Welcome to V-VSS 2021

Over the past months, you – our community of vision scientists – have overcome the significant challenges presented by the pandemic and contributed the research and ideas that will allow us to experience the scientific excitement and camaraderie that are the hallmarks of our annual meeting. Thanks to the work of the Board of Directors, Meeting Perfect, the Student-Postdoc Committee, and many others, we have created a meeting that will enhance scientific communication and exchanges, while providing opportunities to interact with vision researchers all over the globe, and at all professional levels.

Innovations for V-VSS 2021 include improved accessibility by captioning oral presentations, and 'live' poster sessions with video walk-throughs available throughout the meeting. We are hosting our first "Just-in-Time" poster session for undergraduate presenters and encourage all attendees to visit and see what these young scientists have accomplished. We are keeping the tradition of our Public Lecture, virtually, with outreach focused on the communities surrounding our conference home to preserve and develop our networking in this region.

The meeting will be hosted through "Gather.Town", a fun virtual venue that will give you the opportunity to experience each session live, hold impromptu meetings, chat with friends in the courtyard, have a beverage at the tiki hut and hang out on the beach (complete with the sound of surf and dolphins). This important aspect of the meeting would not be possible without the dedication and creativity of our GT crew: Matt Boring, Kate Bonnen, Stacey Aston and Brendan Ritchie.

Thank you for coming to the meeting, and for sharing your science, your ideas and your continuing friendship. See you soon!

Sincerely,
Laurie Wilcox, VSS President

Schedule of Events

All times shown in EDT timezone (America/New_York).

Friday, May 21		
8:00 - 10:00 am	Symposium - Early Processing of Foveal Vision • **Join Zoom**	Talk Room 1
8:00 - 10:00 am	Symposium - Wait for it: 20 years of temporal orienting • **Join Zoom**	Talk Room 2
10:00 - 10:30 am	Coffee Break • **Go to Gather.Town**	Gather.Town
10:30 - 10:35 am	President's Welcome A brief video Welcome by Laurie Wilcox, VSS President, will be played at the beginning of Visual Search and Plasticity and Learning talk sessions.	Talk Room 1-2
10:30 - 11:45 am	Visual Search • **Join Zoom**	Talk Room 1
10:30 am - 12:00 pm	Plasticity and Learning • **Join Zoom**	Talk Room 2
12:00 - 12:30 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
12:30 - 2:00 pm	Attention: Models and mechanisms • **Join Zoom**	Talk Room 1
12:30 - 2:00 pm	3D Perception and Stereopsis • **Join Zoom**	Talk Room 2
2:00 - 2:30 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
2:00 - 3:30 pm	Mentoring Envisioned • **Join Zoom** V-VSS Satellite, Organized by members of FoVea, Visibility and SPARK	Sea Turtle
2:30 - 4:30 pm	Symposium - What we learn about the visual system by studying non-human primates: Past, present and future • **Join Zoom**	Talk Room 1
2:30 - 4:30 pm	Symposium - What has the past 20 years of neuroimaging taught us about human vision and where do we go from here? • **Join Zoom**	Talk Room 2
4:00 - 5:00 pm	Run MATLAB/Psychtoolbox Experiments Online with Pack & Go • **Join Zoom** V-VSS Satellite, Organized by VPixx Technology Inc.	Palm
5:00 - 7:00 pm	Conversations on Open Science • **Join Zoom** Organized by Student Postdoc Advisory Committee	Talk Room 1
7:30 - 8:00 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
8:00 - 9:00 pm	Meet the Professors • **Join Zoom**	Sandpiper
8:00 - 10:00 pm	Canadian Vision Science Social • **Join Zoom** V-VSS Satellite, Hosted by Vision: Science to Applications (VISTA)	Sawgrass
Saturday, May 22		
8:00 - 9:00 am	An introduction to TELLab - The Experiential Learning LABoratory, a web-based platform for educators • **Join Zoom** V-VSS Satellite, Organized by Jeff Mulligan and Jeremy Wilmer	Sea Turtle

8:00 - 10:00 am	Poster Session A • **Go to Gather.Town** Visual Memory: Working, long-term 1 Visual Memory: Encoding Temporal Processing	Osprey
8:00 - 10:00 am	Poster Session A • **Go to Gather.Town** Eye Movements: Cognition, neural mechanisms Scene Perception: Neural mechanisms Object Recognition: Features and parts	Manatee
8:00 - 10:00 am	Poster Session A • **Go to Gather.Town** Perceptual Organization 1 Visual Search: Categories, cues Binocular Vision: Rivalry and competition	Dolphin
8:00 - 10:00 am	Poster Session A • **Go to Gather.Town** Face Perception: Individual differences 1 Perception and Action: Decision making, models, neural mechanisms Perception and Action: Action and body perception 1	Egret
9:15 - 10:15 am	Measuring and Maximizing Eye Tracking Data Quality with EyeLinks • **Join Zoom** V-VSS Satellite, Organized by SR Research Ltd.	Palm
10:00 - 10:30 am	Coffee Break • **Go to Gather.Town**	Gather.Town
10:30 am - 12:00 pm	Attention: Features, objects, salience • **Join Zoom**	Talk Room 1
10:30 am - 12:00 pm	Face Perception: Models and mechanisms • **Join Zoom**	Talk Room 2
12:00 - 12:30 pm	New Tools for Conducting Eye Tracking Research • **Join Zoom** V-VSS Satellite, Organized by Eyeware	Palm
12:00 - 1:00 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
12:00 - 1:00 pm	US Funding Workshop • **Join Zoom**	Sea Turtle
1:00 - 2:00 pm	Keynote Lecture: Suzana Herculano-Houzel • **Join Zoom**	Talk Room 1-2
2:00 - 2:30 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
2:30 - 4:00 pm	Spatial Vision • **Join Zoom**	Talk Room 1
2:30 - 4:00 pm	Development • **Join Zoom**	Talk Room 2
4:00 - 4:30 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
4:30 - 5:30 pm	2020 Awards Session • **Join Zoom**	Talk Room 1-2
5:30 - 6:00 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
8:00 - 10:00 pm	Attention, Search, Memory, Crowding • **Join Zoom**	Talk Room 1
10:00 - 10:30 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
	Sunday, May 23	
8:00 - 9:00 am	Run MATLAB/Psychtoolbox Experiments Online with Pack & Go • **Join Zoom** V-VSS Satellite, Organized by VPixx Technology Inc.	Sea Turtle

8:00 - 10:00 am	Poster Session B • **Go to Gather.Town** Spatial Vision: Crowding Spatial Vision: Models Visual Memory: Neural mechanisms Visual Memory: Imagery, drawing, scenes	Osprey
8:00 - 10:00 am	Poster Session B • **Go to Gather.Town** Plasticity and Learning 1 Attention: Objects Attention: Inattention and lapses	Manatee
8:00 - 10:00 am	Poster Session B • **Go to Gather.Town** Perception and Action: Navigation Perception and Action: Reaching, pointing and grasping 1 Perception and Action: Virtual environments 1 Attention: Neural Attention: Spatial, features	Dolphin
8:00 - 10:00 am	Poster Session B • **Go to Gather.Town** Face Perception 2 Object Recognition: Dynamics Eye Movements: Saccades, cognition, neural mechanisms	Egret
10:00 - 10:30 am	Coffee Break • **Go to Gather.Town**	Gather.Town
10:30 am - 12:00 pm	Visual Memory: Working and long-term • **Join Zoom**	Talk Room 1
10:30 am - 12:00 pm	Perception and Action • **Join Zoom**	Talk Room 2
12:00 - 12:30 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
12:30 - 2:00 pm	Motion Perception • **Join Zoom**	Talk Room 1
12:30 - 2:00 pm	Eye movements: Saccades, pursuit, vergence • **Join Zoom**	Talk Room 2
2:00 - 2:30 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
2:30 - 3:30 pm	2021 Awards Session • **Join Zoom**	Talk Room 1-2
3:30 - 4:00 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
3:30 - 5:30 pm	phiVIS: Philosophy of Vision Science Workshop • **Join Zoom** V-VSS Satellite, Organized by Kevin Lande and Chaz Firestone	Sea Turtle
4:00 - 6:00 pm	Poster Session C • **Go to Gather.Town** Face Perception: Features and configurations Face Perception: Individual differences 2	Osprey
4:00 - 6:00 pm	Poster Session C • **Go to Gather.Town** Color, Light and Material: Lightness and brightness Color, Light and Material: Color 1 Color, Light and Material: Cognition and preference 1 Scene Perception: Cognitive processes 1	Manatee
4:00 - 6:00 pm	Poster Session C • **Go to Gather.Town** Attention: Divided, models, objects and cues Binocular Vision: Stereopsis	Dolphin
4:00 - 6:00 pm	Poster Session C • **Go to Gather.Town** Visual Search: Attention, individual differences	Egret

6:00 - 6:30 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
6:00 - 7:00 pm	An introduction to TELLab - The Experiential Learning LABoratory, a web-based platform for educators • **Join Zoom** V-VSS Satellite, Organized by Jeff Mulligan and Jeremy Wilmer	Sea Turtle
8:00 - 10:00 pm	Just-In-Time Poster Session A • **Go to Gather.Town** Undergraduate Just-In-Time Posters 1	Flamingo
8:00 - 10:00 pm	Poster Session D • **Go to Gather.Town** Face Perception 1 Multisensory Processing 1	Osprey
8:00 - 10:00 pm	Poster Session D • **Go to Gather.Town** Color, Light and Material Eye movements	Manatee
8:00 - 10:00 pm	Poster Session D • **Go to Gather.Town** Motion Perception 1 Spatial and Temporal Vision	Dolphin
10:00 - 10:30 pm	Coffee Break • **Go to Gather.Town**	Gather.Town

Monday, May 24

8:45 - 10:45 am	Reunion: Visual Neuroscience From Spikes to Awareness • **Join Zoom** V-VSS Satellite, Organized by Arash Akbarinia	Palm
9:00 - 9:30 am	Coffee Break • **Go to Gather.Town**	Gather.Town
9:00 - 9:30 am	New Tools for Conducting Eye Tracking Research • **Join Zoom** V-VSS Satellite, Organized by Eyeware	Sea Turtle
9:30 - 11:30 am	Symposium - Feedforward & Recurrent Streams in Visual Perception • **Join Zoom**	Talk Room 1
9:30 - 11:30 am	Symposium - What's new in visual development? • **Join Zoom**	Talk Room 2
11:00 am - 12:00 pm	Visibility: A Gathering of LGBTQ+ Vision Scientists and Friends • **Join Zoom** V-VSS Satellite, Organized by Alex White and Michael Grubb	Sawgrass
11:30 am - 12:00 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
12:00 - 1:30 pm	Color, Texture and Material • **Join Zoom**	Talk Room 1
12:00 - 1:30 pm	Scene Perception • **Join Zoom**	Talk Room 2
2:00 - 3:00 pm	VSS Business Meeting • **Join Zoom**	Talk Room 1
3:00 - 3:30 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
3:00 - 4:00 pm	Measuring and Maximizing Eye Tracking Data Quality with EyeLinks • **Join Zoom** V-VSS Satellite, Organized by SR Research Ltd.	Sea Turtle
3:30 - 5:30 pm	Poster Session E • **Go to Gather.Town** Visual Memory: Working, long-term 2 Perception and Action: Action and body perception 2	Osprey
3:30 - 5:30 pm	Poster Session E • **Go to Gather.Town** Perceptual Organization 2	Manatee

	Perceptual Organization: Contours and shape Motion Perception: Models and neural mechanisms	
3:30 - 5:30 pm	Poster Session E • **Go to Gather.Town** Attention: Individual differences, spatiotemporal Multisensory Processing 2	Dolphin
3:30 - 5:30 pm	Poster Session E • **Go to Gather.Town** 3D Perception: Models, neural mechanisms 3D Perception: Real and virtual environments Object Recognition: Categories 1	Egret
4:15 - 6:15 pm	Teaching Vision • **Join Zoom** V-VSS Satellite, Organized by Dirk Bernhardt-Walther	Palm
5:30 - 6:00 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
8:00 - 9:00 pm	An introduction to TELLab 2.0 - A new-and-improved version of The Experiential Learning LABoratory, a web-based platform for educators • **Join Zoom** V-VSS Satellite, Organized by Jeff Mulligan and Jeremy Wilmer	Sea Turtle
8:00 - 10:00 pm	Poster Session F • **Go to Gather.Town** Attention Visual Search	Osprey
8:00 - 10:00 pm	Poster Session F • **Go to Gather.Town** Visual Memory Scene Perception Perception and Action	Manatee
8:00 - 10:00 pm	Poster Session F • **Go to Gather.Town** Object Recognition Binocular Vision	Dolphin
10:00 - 10:30 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
	Tuesday, May 25	
8:00 - 10:00 am	Just-In-Time Poster Session B • **Go to Gather.Town** Undergraduate Just-In-Time Posters 2	Flamingo
8:00 - 10:00 am	Poster Session G • **Go to Gather.Town** Attention: Individual differences, spatiotemporal, reward, social Attention: Divided, models Development	Osprey
8:00 - 10:00 am	Poster Session G • **Go to Gather.Town** Object Recognition: Neural mechanisms Color, Light and Material: Surfaces and materials Color, Light and Material: Color 2 Color, Light and Material: Cognition and preference 2	Manatee
8:00 - 10:00 am	Poster Session G • **Go to Gather.Town** Visual Search: Spatial, temporal, memory Decision Making	Dolphin
8:00 - 10:00 am	Poster Session G • **Go to Gather.Town** 3D Perception: Cue combination 3D Perception: Shape 3D Perception: Stereopsis, models and mechanisms Face Perception: Neural mechanisms Face Perception: Models and metrics	Egret

9:15 - 10:15 am	Performing Eye Tracking Studies in VR • **Join Zoom** V-VSS Satellite, Organized by WorldViz VR	Sea Turtle
10:00 - 10:30 am	Coffee Break • **Go to Gather.Town**	Gather.Town
10:30 am - 12:00 pm	Perceptual Organization • **Join Zoom**	Talk Room 1
10:30 am - 12:00 pm	Eye Movements: Extra-retinal processes, scanpaths • **Join Zoom**	Talk Room 2
12:00 - 1:00 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
12:00 - 1:00 pm	Virtual VPixx Hardware with the LabMaestro Simulator • **Join Zoom** V-VSS Satellite, Organized by VPixx Technology Inc.	Sea Turtle
12:00 - 1:00 pm	Meet the Professors • **Join Zoom**	Sandpiper
12:00 - 1:00 pm	Public Lecture • **Join Zoom** Roland Fleming, "Big Data and the Brain: How we Learn to See 'Stuff' from Lots and Lots of Examples"	Zoom Room
1:00 - 2:30 pm	Multisensory Processing • **Join Zoom**	Talk Room 1
1:00 - 2:30 pm	Visual Memory: Capacity, models, neural and encoding • **Join Zoom**	Talk Room 2
2:30 - 3:00 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
2:30 - 4:30 pm	Reunion: Visual Neuroscience From Spikes to Awareness • **Join Zoom** V-VSS Satellite, Organized by Arash Akbarinia	Palm
3:00 - 5:00 pm	Poster Session H • **Go to Gather.Town** Eye Movements: Neural mechanisms Spatial Vision: Neural Mechanisms 1	Osprey
3:00 - 5:00 pm	Poster Session H • **Go to Gather.Town** Plasticity and Learning 2 Scene Perception: Models and statistics	Manatee
3:00 - 5:00 pm	Poster Session H • **Go to Gather.Town** Attention: Capture 1 Spatial Vision: Psychophysics 1	Dolphin
3:00 - 5:00 pm	Poster Session H • **Go to Gather.Town** Perception and Action: Virtual environments 2 Perception and Action: Reaching, pointing and grasping 2 Perception and Action: Affordances Perception and Action: Neural mechanisms 1	Egret
5:00 - 5:30 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
5:00 - 5:30 pm	Peer Review of NIH NRSA Fellowship Proposals • **Join Zoom**	Sea Turtle
5:15 - 6:15 pm	Performing Eye Tracking Studies in VR • **Join Zoom** V-VSS Satellite, Organized by WorldViz VR	Palm
8:00 - 10:00 pm	Face Perception • **Join Zoom**	Talk Room 1
10:00 - 10:30 pm	Coffee Break • **Go to Gather.Town**	Gather.Town

Wednesday, May 26

8:00 - 10:00 am	Poster Session I • **Go to Gather.Town** Attention: Capture 2 Visual Search: Attention, models, individual differences Object Recognition: Models Object Recognition: Categories 2	Osprey
8:00 - 10:00 am	Poster Session I • **Go to Gather.Town** Eye Movements: Perception, neural mechanisms Motion Perception 2	Manatee
8:00 - 10:00 am	Poster Session I • **Go to Gather.Town** Scene Perception: Cognitive processes 2 Perception and Action: Neural mechanisms 2 Spatial Vision: Psychophysics 2 Spatial Vision: Neural Mechanisms 2	Dolphin
8:00 - 10:00 am	Poster Session I • **Go to Gather.Town** Visual Memory: Capacity and content Multisensory Processing 3	Egret
8:30 - 10:30 am	Teaching Vision • **Join Zoom** V-VSS Satellite, Organized by Dirk Bernhardt-Walther	Sea Turtle
10:00 - 10:30 am	Coffee Break • **Go to Gather.Town**	Gather.Town
10:30 am - 12:00 pm	Objects and Scenes: Models and mechanisms • **Join Zoom**	Talk Room 1
10:30 am - 12:00 pm	Decision Making • **Join Zoom**	Talk Room 2
12:00 - 1:00 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
12:00 - 1:00 pm	Connect with Industry • **Join Zoom** Interact with reps from Industy & Goverment agencies	Sandpiper
1:00 - 2:30 pm	Cortical Hierarchy and Computation • **Join Zoom**	Talk Room 1
1:00 - 2:30 pm	Face Perception: Psychophysics • **Join Zoom**	Talk Room 2
2:30 - 3:00 pm	Coffee Break • **Go to Gather.Town**	Gather.Town
2:30 - 3:30 pm	An introduction to TELLab 2.0 - A new-and-improved version of The Experiential Learning LABoratory, a web-based platform for educators • **Join Zoom** V-VSS Satellite, Organized by Jeff Mulligan and Jeremy Wilmer	Sea Turtle
4:00 - 6:00 pm	Club Vision • **Join Zoom**	Beach

President's Welcome

Laurie Wilcox

Friday, May 21, 10:30 - 10:35 am EDT, Talk Room 1-2 **Join Zoom Talk Room 1**, **Join Zoom Talk Room 2**

There will be a brief Welcome to V-VSS 2021 from Laurie Wilcox, the current VSS President, at the start of the Friday talk sessions. Please join us at the start of either the **Visual Search** session in Talk Room 1 or **Plasticity and Learning** session in Talk Room 2 for this presentation.

Keynote Lecture

Saturday, May 22, 1:00 - 2:00 pm EDT, Talk Room 1-2 Join Zoom Webinar

*The Keynote Lecture is sponsored by **VPixx Technologies**.*

Suzana Herculano-Houzel

Associate Professor of Psychology and Associate Director for Communications
Vanderbilt Brain Institute

Suzana Herculano-Houzel, Ph.D., is a biologist and neuroscientist at Vanderbilt University, where she is Associate Professor in the Departments of Psychology and Biological Sciences. Her research focuses on what different brains are made of; what that matters in terms of cognition, energy cost, and longevity; and how the human brain is remarkable, but not special, in its makeup. She is the author of The Human Advantage (MIT Press, 2016), in which she tells the story of her discoveries on how many neurons different species have—and how the number of neurons in the cerebral cortex of humans is the largest of them all, thanks to the calories amassed with a very early technology developed by our ancestors: cooking. She spoke at TEDGlobal 2013 and TEDxNashville 2018 and is an avid communicator of science to the general public.

To learn more about Professor Herculano-Houzel and her research, please visit her website.

Whatever works: Celebrating diversity in brain scaling and evolution

Animals come in many sizes and shapes, and one would be hard-pressed to say that any one is better than the other, because all of them have passed the test of evolution: they're here, so they have obviously been good enough. Still, what weighs on the trade-off scale when animals and their brains vary in size? What can be said about scaling of the visual system, in particular? What does it cost to have more neurons? Is it even necessary for larger animals to have more neurons? This talk will tackle the old topic of scaling in a new light that celebrates diversity, rather than assume that biology is improved through natural selection.

2020 Awards Session

Saturday, May 22, 4:30 - 5:30 pm EDT, Talk Room 1-2 Join Zoom Webinar

Timothy Brady, Marlene Behrmann, and Ted Adelson will speak during the 2020 Awards Session.

Young Investigator Award

Timothy Brady
Assistant Professor, Department of Psychology, University of California, San Diego

Davida Teller Award

Marlene Behrmann
University Professor of Psychology and Neuroscience, Carnegie Mellon University

Ken Nakayama Medal for Excellence in Vision Science

Edward 'Ted' Adelson
John and Dorothy Wilson Professor of Vision Science, MIT

Graphics Competition Winner

Georgin Jacob

Elsevier/*Vision Research* Travel Awards

89 Students received a 2020 Travel Award funded by Elsevier/*Vision Research*.

2020 Awards Session >

2020 Young Investigator Award

Saturday, May 22, 4:30 - 5:30 pm EDT, Talk Room 1-2 Join Zoom Webinar

The Vision Sciences Society is honored to present Timothy Brady with the 2020 Young Investigator Award.

VISION RESEARCH

Elsevier/Vision Research International Travel and Young Investigator Awards sponsors VSS 2020

The Young Investigator Award is an award given to an early stage researcher who has already made a significant contribution to our field. The award is sponsored by Elsevier, and the awardee is invited to submit a review paper to Vision Research highlighting this contribution.

The 2020 Young Investigator Award was sponsored by ***Elsevier/Vision Research****.*

Timothy Brady

Assistant Professor, Department of Psychology
University of California, San Diego

The 2020 Elsevier/VSS Young Investigator Award goes to Professor Timothy Brady for his fundamental contributions to the scientific study of visual memory. Tim Brady is an Assistant Professor at the Department of Psychology, UCSD. After completing his undergraduate degree in Cognitive Science at Yale University, Prof Brady did his PhD with Aude Oliva at MIT and then post-doctoral research with George Alvarez at Harvard University.

Professor Brady uses a combination of behavioral methods, cognitive neuroscience techniques and computational modelling to probe representations in the visual system and the processes by which visual information is encoded in working memory and integrated into long-term storage. He has made numerous surprising discoveries about the extreme fidelity and detail of visual long-term memories for objects and scenes, and has demonstrated how statistical learning and ensemble encoding of features facilitates the maintenance and storage of complex stimuli like natural scenes. Prof Brady's work has helped broaden the study of working memory to include richer, more naturalistic stimuli, and repeatedly challenged long-standing assumptions about the nature of visual representations. In a series of highly-cited studies he has shown how remembered objects are stored as groups of distinct parts that can be independently forgotten, and that when multiple items must be remembered, the brain computes summary statistics across the group. Prof Brady is not only a gifted and productive experimentalist—he has also made substantial contributions to the theoretical understanding of visual memory representations through computational modelling, as well as providing numerous useful tools for the community.

Professor Brady will speak during the 2020 Awards session.

The nature of visual memory

In the real world, objects are discrete physical entities – your coffee mug either is or is not in your hand. As a result, both in everyday life and in memory research, there is a tendency to use a physical metaphor to understand memory: people tend to think of an object they are trying to remember as either in mind or not in their mind, and to say that we hold items in mind, as we hold real objects in our hand. This metaphor serves as a core mental model used in most conceptions of memory: all-or-none, discrete, and functioning at the level of entire objects or other discrete representations or chunks. In this brief talk, I'll argue for a new way of thinking about memory that strongly contrasts with this common and intuitive view. I'll show that individuated items are far from the only kind of representation people form, and that it is necessary to consider interactions among an entire hierarchy of representations (from semantic knowledge to ensemble information, chunks and items) to understand memory even for a single item. Next, I'll show that memory representations, even for single items, are population-based and continuous in strength. Altogether, I'll argue that even for those interested in cognition, analogies from neuroscience — with population codes, hierarchical representations and noisy signals — best allow us to understand memory limits, rather than physical analogies about discrete items.

2020 Davida Teller Award

Saturday, May 22, 4:30 - 5:30 pm EDT, Talk Room 1-2 Join Zoom Webinar

The Vision Sciences Society is honored to present Dr. Marlene Behrmann with the 2020 Davida Teller Award

VSS established the Davida Teller Award in 2013. Davida was an exceptional scientist, mentor and colleague, who for many years led the field of visual development. The award is therefore given to an outstanding female vision scientist in recognition of her exceptional, lasting contributions to the field of vision science.

Marlene Behrmann

University Professor of Psychology and Neuroscience, Carnegie Mellon University

Marlene Behrmann received her B.A. in Speech and Hearing Therapy in 1981, followed by her M.A. in Speech Pathology in 1984, both from the University of Witwatersrand in Johannesburg, South Africa. She then obtained a Ph.D. in Psychology from the University of Toronto in 1991. She was a Research Scientist at the Rotman Research Institute in Toronto before moving to Carnegie Mellon University in 1993, where she is currently a University Professor of Psychology and Neuroscience. Dr. Behrmann was elected a member of the Society for Experimental Psychologists in 2008, inducted into the National Academy of Sciences in 2015, and into the American Academy of Arts and Sciences in 2019. Her prior recognitions include the Presidential Early Career in Science and Engineering and the Fred Kavli Distinguished Career Contributions in Cognitive Neurosciences Award.

Dr. Behrmann is a trailblazer and a world leader in the field of visual cognition. Her work represents the best of cognitive neuroscience, seamlessly blending insights gained from neuropsychology, modeling, cutting-edge functional and structural brain imaging, and behavioral experiments. She has made major contributions across a wide range of topics, including attention, the neural basis of autism, specialization between hemispheres in the brain, face recognition and disorders of face recognition, visual object recognition, word recognition, and visual imagery. Dr. Behrman's work is characterized by her remarkable ability to examine an issue rigorously from many vantage points, and from there to develop, test, and refine theories of how a given behavior arises from the underlying brain function. In addition, she has an exceptional record of mentorship throughout her career in promoting and supporting students at all stages. Dr. Behrmann embodies the characteristics that we so admired in Davida Teller, and it is with pride that the Society recognizes her accomplishments through the Davida Teller Award.

Dr. Behrmann will speak during the 2020 Awards session.

Hemispheric organization and pattern recognition

Despite the overall similarity in structure, the two hemispheres of the human brain have somewhat different functions. A traditional view of hemispheric organization asserts that there are independent and largely lateralized domain-specific visual regions in ventral occipitotemporal, specialized, if not dedicated, and perhaps innate, for the recognition of distinct classes of objects such as words and faces. In this talk, I will offer an alternative account of the organization of the hemispheres. I will present an account of interactive and graded organization of both within- and between-hemisphere organization. The crux of the account is that mature hemispheric organization emerges from a competitive and collaborative dynamic in which in right-handers, during the acquisition of literacy, word recognition comes to be co-localized with language lateralization in the left hemisphere. Consequently, face recognition is shifted, albeit not entirely, to the right hemisphere. Behavioral and imaging data from adults and over development will provide evidence to support this hypothesis of graded asymmetry.

Last, I will show that this pattern of organization is malleable and that, in children who have had a unilateral posterior cortical resection, the preserved hemisphere can subserve both word and face recognition. Together, these findings support a dynamic interactive process by which hemispheric organization emerges and unfolds with experience.

2020 Ken Nakayama Medal for Excellence in Vision Science

Saturday, May 22, 4:30 - 5:30 pm EDT, Talk Room 1-2 Join Zoom Webinar

The Vision Sciences Society is honored to present Edward Adelson with the 2020 Ken Nakayama Medal for Excellence in Vision Science.

The Ken Nakayama Medal is in honor of Professor Ken Nakayama's contributions to the Vision Sciences Society, as well as his innovations and excellence to the domain of vision sciences.

The recipient of the Ken Nakayama Medal receives this honor for high-impact work that has made a lasting contribution in vision science in the broadest sense. The nature of this work can be fundamental, clinical or applied.

Edward 'Ted' Adelson

John and Dorothy Wilson Professor of Vision Science, MIT

Edward 'Ted' Adelson received his B.A. in Physics & Philosophy in 1974 from Yale University, followed by a PhD in Experimental Psychology from the University of Michigan (1979). After a postdoctoral position at NYU he became a research scientist at RCA labs. Ted then joined the faculty at MIT in 1987, first in the Media Lab, before moving to the department of Brain & Cognitive Sciences in 1994. Currently, Ted is the John and Dorothy Wilson Professor of Vision Science at MIT, in the Department of Brain and Cognitive Sciences, and in the Computer Science and Artificial Intelligence Laboratory (CSAIL). Ted has received many prior awards and is a Member of the National Academy of Sciences.

Over his career Ted has made fundamental and wide-ranging contributions to the scientific study of vision and perception. His work is the stuff of textbooks and perception courses, and the illusions he has discovered have inspired and beguiled researchers and the general public alike. Indeed, Ted is able to bring visual phenomena to a highly purified state, so that his demonstrations will remain standard references for generations to come. More generally, Ted's work bridges across the full range of vision science, and includes seminal contributions to theory, psychophysics, computational modelling, and neurophysiology. From low-level mechanisms of retinal adaptation, to the motion energy model, texture processing, lightness perception, pyramid decompositions, the plenoptic function, 'things' vs 'stuff' and material perception, practically everything Ted has done has opened new avenues of investigation and understanding in ways that have helped define the field. He is also known as an amazing supervisor, and many of his trainees have themselves gone on to make fundamental contributions to our understanding of vision. Ted Adelson easily meets, several times over, the Nakayama Award's criterion of having made exceptional, lasting contributions to vision science.

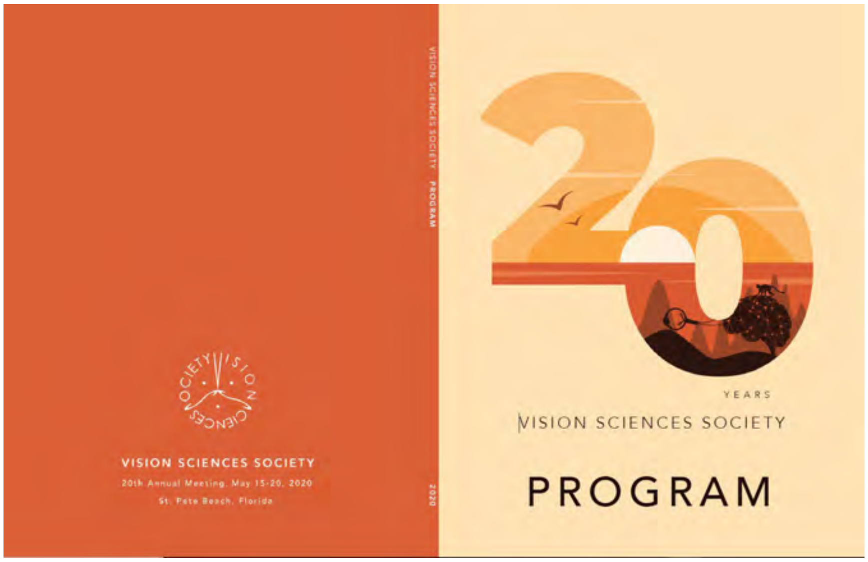
Dr. Adelson will speak during the 2020 Awards session.

2020 Graphics Competition Winner

Saturday, May 22, 4:30 - 5:30 pm EDT, Talk Room 1-2 **Join Zoom Webinar**

The Vision Sciences Society is pleased to recognize Georgin Jacob as the winner of the V-VSS 2020 Graphics Competition for both the Program Cover and T-shirt Design.

Each year VSS solicits its membership to submit creative visual images related to the field of vision science, the Society, or the VSS meeting. Traditionally, the winning images are featured on the program, abstracts book, signage, and t-shirts. Due COVID's impact on the 2020 meeting, the winning graphics were not able to be fully featured.



Program Cover Competition

This abstract portrays the research life of a vision scientist. A monkey exploring the tree symbolizes a researcher trying hard to understand the complexities of the brain. The bright spots on the tree tell what we know about the brain, and the connected line shows the importance of collaborating and sharing the work. The hills and valleys represent the ups and downs in research life, while the horizon shows the passion and hope that drives the research forward. The orange and yellow background expresses the calm and pleasing view of "St. Pete's Beach," the venue of all VSS meetings. Twenty signifies the 20th anniversary of the remarkable journey of VSS in connecting worldwide vision researchers.

Special thanks to my friend Vaisakh Pradeep, my colleagues at IISc, and the VSS organizers for their constructive feedback on the design.

T-shirt Design Competition

Georgin also won the graphic competition for the T-shirt design. Because VSS 2020 was a virtual event, no T-shirts were printed. Instead, Georgin's T-shirt image was incorporated into the website banner for the virtual meeting.

About Georgin Jacob

Georgin Jacob received his B. Tech in Electronics and Communication from RIT Kottayam, India. He then obtained his M. Tech in Signal Processing from CET Trivandrum, India. Before joining for Ph.D., he was working as Junior Research Fellow at NPOL, DRDO, India. Currently, he is doing Ph.D. in Electrical Communication Engineering under the supervision of Dr. S. P. Arun at the Indian Institute of Science, Bangalore, India. His current research aims to understand the organization of visual representation in our brain and model the computations that lead to a decision during visual tasks. His research interest includes visual perception, deep learning, and cognitive neuroscience.

2020 Awards Session >

2020 Elsevier/*Vision Research* Travel Awards

Saturday, May 22, 4:30 - 5:30 pm EDT, Talk Room 1-2 Join Zoom Webinar

VSS is grateful to **Elsevier/*Vision Research*** for their generous support of this year's virtual meeting. Congratulations to the following VSS student and postdoc members who received a V-VSS 2020 Elsevier/*Vision Research* Travel Award, which allows them to present at V-VSS at no additional cost.

Aakash Agrawal, Indian Institute of Science, India
Emily J. Allen, University of Minnesota, US
Jordi Asher, University of Essex, UK
Celine Aubuchon, Brown University, US
Lauren S. Aulet, Emory University, US
Vladislav Ayzenberg, Emory University, US
Carolyn Baer, University of British Columbia, Canada
Elizabeth Bennette, University of California, San Diego, US
Bruno Bianchi, University of Buenos Aires, Argentina
Sage Boettcher, University of Oxford, UK
Ann Carrigan, Macquarie University, Australia
Cristina Ceja, Northwestern University, US
Oakyoon Cha, Vanderbilt University, US
Angus Chapman, University of California San Diego, US
William Charles, Fordham University, US
Yi-Chia Chen, Harvard University, US
Andrey Chetverikov, Radboud University, Netherlands
Martin Constant, Ludwig Maximilian University of Munich, Germany
Shanna Coop, University of Rochester, US
Cristina de la Malla, Universitat de Barcelona, Spain
Madison Elliott, University of British Columbia, Canada
Serra Favila, Columbia University, US
Julie Freschl, University of Massachusetts Boston, US
Ashley Funkhouser, The University of Southern Mississippi, US
Josselin Gautier, University of California Berkeley, US
Robert Geirhos, University of Tuebingen, Germany
Erin Goddard, University of New South Wales, Australia
Amanda Golden Eddy, California State University, Fullerton, US
Lukasz Grzeczkowski, Ludwig-Maximilian University, Germany
Susan Hao, UC Berkeley, US
Christopher I. Hernandez, University of Central Florida, US
Sirawaj Itthipuripat, King Mongkut's University of Technology Thonburi, Thailand
Oliver Jacobs, University of British Columbia, Canada
Akila Kadambi, UCLA, US
Philipp Kaniuth, Max Planck Institute, Germany
Harun Karimpur, University Giessen, Germany
Sarah Kerns, Wellesley College, US
Vladislav Khvostov, NRU Higher School of Economics, Russia
Kaleb T. Kinder, University of Tennessee – Knoxville, US
Maria Kon, Purdue University, US
Anna Kosovicheva, Northeastern University, US
Rebecca Kozak, Western University, US
Jessica Kubert, Emory University, US

Eline R. Kupers, New York University, US
Anna Leshinskaya, UC Davis, US
Xian Li, Harvard Medical School, US
Ming-Ray Liao, Texas A&M University, US
Ying Lin, University of Rochester, US
Paul Linton, University of London, UK
Ghazaleh Mahzouni, University of California, Santa Cruz, US
Miles Martinez, Brown University, US
Ankit Maurya, S R Engineering College, India
Maruti Mishra, Harvard Medical School, US
Austin Moon, University of California, Riverside, US
Annie Morsi, University College London, UK
Matthias Nau, Kavli Institute for Systems Neuroscience, US
Karen Navarro, University of Minnesota, US
Asal Nouri, Florida Atlantic University, US
Joan Danielle K. Ongchoco, Yale University, US
Su Hyoun Park, University of Delaware, US
Ruben Pastilha, Newcastle University, UK
Karissa B. Payne, Kansas State University, US
Charisse B. Pickron, University of Minnesota, US
Ulrich Pomper, University of Vienna, Austria
Jacob S. Prince, Harvard University, US
Rebecca E. Ranson, Essex University, UK
Leeland Rogers, University of Delaware, US
Tiasha Saha Roy, Indian Institute of Science Education and Research Kolkata, India
Christine Salahub, Brock University, Canada
Marco Sama, University of Toronto Scarborough, Canada
D. Merika W. Sanders, University of Massachusetts Amherst, US
Lindsay Santacroce, University of Houston, US
Dawn Sarno, University of Central Florida, US
Svea C. Y. Schroeder, University of Muenster, Germany
Juan Sepulveda, The University of Melbourne, Australia
Sabyasachi Shivkumar, University of Rochester, US
Andrew Silva, University of Waterloo, Canada
Caitlin Sisk, University of Minnesota, US
Elena Sizikova, New York University, US
Emily Slezak, University of Chicago, US
Maverick Smith, Kansas State University, US
Mirta Stantic, University of Oxford, UK
Adam Steel, Dartmouth College, US
Vijay K. Tailor, University College London, UK
Melissa Trevino, National Cancer Institute, US
Domenico Tullo, McGill University, Canada
Jan Tünnermann, Philipps University of Marburg, Germany
Michele Winter, University of California, Berkeley, US
Sami Yousif, Yale University, US

2021 Awards Session

Sunday, May 23, 2:30 - 3:30 pm EDT, Talk Room 1-2 Join Zoom Webinar

*The 2021 Awards Session is sponsored by **Facebook Reality Labs**.*

Martina Poletti, Marisa Carrasco, and Gerald Westheimer will speak during the 2021 Awards Session.

Young Investigator Award

Martina Poletti
Assistant Professor, Department of Brain and Cognitive Sciences, University of Rochester

Davida Teller Award

Marisa Carrasco
Julius Silver Professor of Psychology and Neural Science, New York University

Ken Nakayama Medal for Excellence in Vision Science

Gerald Westheimer

Graphics Competition Winner

Susanne Stoll

Elsevier/*Vision Research* Travel Awards

98 Graduate Students and 35 Postdoc Members will receive a 2021 Travel Award funded by Elsevier/*Vision Research*.

2021 Young Investigator Award

Sunday, May 23, 2:30 - 3:30 pm EDT, Talk Room 1-2 Join Zoom Webinar

The Vision Sciences Society is honored to present Martina Poletti with the 2021 Young Investigator Award.

The Young Investigator Award is an award given to an early stage researcher who has already made a significant contribution to our field. The award is sponsored by Elsevier, and the awardee is invited to submit a review paper to Vision Research highlighting this contribution.

The 2021 Young Investigator Award is sponsored by ***Elsevier/Vision Research****.*

Martina Poletti

Assistant Professor, Department of Brain and Cognitive Sciences, University of Rochester

The 2021 Elsevier/VSS Young Investigator Award goes to Dr. Martina Poletti for fundamental contributions to our understanding of eye movements, microsaccades, and the nature of visual-motor function and attention within the foveola. Dr. Poletti is an Assistant Professor in the Department of Brain and Cognitive Sciences at the University of Rochester. She received her Bachelor's degree and Master's degree at the University of Padova, and completed her doctoral and postdoctoral work at Boston University.

Dr. Poletti's research addresses core questions regarding the interplay of attention and eye movements at the foveal scale. Her scholarly contributions will help revise textbook descriptions of the central fovea as a region of uniformly high acuity and microsaccades as involuntary eye movements, which purpose is to merely refresh the retinal image during fixation. Dr. Poletti's experiments have capitalized on high-resolution eye tracking and gaze-contingent display to demonstrate that microsaccades are not random but purposeful, serving to bring task-relevant items to the preferred region within the foveola. Her work has revealed that fine spatial vision within the 1-deg foveola is non-uniform and it is selectively modulated by attention. Within this microcosm of visual space, covert and overt shifts of attention can still be observed operating with a remarkably high-precision, and guiding microsaccades in an active exploration of details. Dr. Poletti's research exemplifies creative experimentation, cutting-edge methodology, and rigorous evaluation of longstanding theories in vision science.

Dr. Poletti will speak during the 2021 Awards session.

The interplay of attention and eye movements at the foveal scale

Human vision relies on a tiny region of the retina, the foveola, to achieve high spatial resolution. Foveal vision is of paramount importance in daily activities, yet its study is challenging, as eye movements incessantly displace stimuli across this region. Building on recent advances in eye-tracking and gaze-contingent display, we have examined how attention and eye movements operate at the foveal level. We have shown that exploration of fine spatial detail unfolds following visuomotor strategies reminiscent of those occurring at larger scales. Together with highly precise control of attention, this motor activity is linked to non-homogenous processing within the foveola and selectively modulates sensitivity both in space and time. Therefore, high acuity vision is not the mere consequence of placing a stimulus at the center of gaze: it is the outcome of a synergy of motor, cognitive, and attentional processes, all finely tuned and dynamically orchestrated.

2021 Davida Teller Award

Sunday, May 23, 2:30 - 3:30 pm EDT, Talk Room 1-2 Join Zoom Webinar

The Vision Sciences Society is honored to present Dr. Marisa Carrasco with the 2021 Davida Teller Award

VSS established the Davida Teller Award in 2013. Davida was an exceptional scientist, mentor and colleague, who for many years led the field of visual development. The award is therefore given to an outstanding female vision scientist in recognition of her exceptional, lasting contributions to the field of vision science.

Marisa Carrasco

Julius Silver Professor of Psychology and Neural Science, New York University

Marisa Carrasco investigates visual perception and attention, using human psychophysics, neuroimaging, neurostimulation, and computational modeling in order to study the relation between the psychological and neural mechanisms involved in these processes. Her research has revealed how attention modulates perceptual performance and alters appearance in a variety of visual tasks. Marisa grew up in Mexico City and earned her Licentiate in Psychology, specializing in experimental psychology, from the National Autonomous University of Mexico (UNAM), where she graduated summa cum laude. Marisa then obtained her MS and PhD in psychology, specializing in cognition and perception, from Princeton University, where she received the highest scholarly excellence award, the Jacobus Honorific Fellowship. She became an Assistant Professor of Psychology at Wesleyan University in 1989. While at Wesleyan Dr. Carrasco received an NSF Young Investigator Award and an American Association of University Women Fellowship. She joined NYU in 1995 as an Associate Professor and was promoted to Professor of Psychology and Neural Science in 2002. She served as chair of the NYU Psychology Department from 2001-2007. NIH and NSF have continuously supported Carrasco's research at NYU.

Professor Carrasco received a Guggenheim Fellowship and a Cattell Fellowship and was named a fellow of the American Psychological Society and has been elected to the National Academy of Sciences (2021); at NYU, she has been Collegiate Professor since 2007 and was named Julius Silver Professor of Psychology and Neural Science in 2019. Among her many other contributions to the vision sciences community, Marisa Carrasco has served as president of both the Vision Sciences Society and the Association for the Scientific Study of Consciousness and as a senior editor of two scientific journals, *Journal of Vision* and *Vision Research*.

Marisa Carrasco has had a profound impact on the field of vision science and attention through her multi-disciplinary research and through her mentorship activity. She is well-known as a dedicated teacher and mentor of undergraduate students, graduate students and post-doctoral fellows. This is in part evidenced by her receipt of the NYU award for excellence in postdoc mentoring in 2018.

Marisa forged her research career in an era when the field of vision science had few women. Through her efforts she not only advanced her own research; she has also been an invaluable and generous role model for the many students she has taught and mentored through the years. With this award, VSS recognizes Professor Marisa Carrasco's outstanding research and thanks her for being a wonderful scientist, mentor, and colleague.

Dr. Carrasco will speak during the 2021 Awards session.

Attention Shapes Perception

Visual attention is essential for visual perception. Spatial attention allows us to grant priority in processing and selectively process information at a given location. In this brief talk, I will illustrate how endogenous (voluntary) and exogenous (involuntary) attention differentially modulate visual perception. I will highlight findings from: (1) psychophysical experiments investigating how endogenous and exogenous covert attention alter tasks mediated by basic visual dimensions as well as their featural representations; (2) neuroimaging (fMRI) experiments differentiating effects of endogenous and exogenous attention on occipital cortex; (3) neurostimulation experiments establishing that transcranial magnetic stimulation (TMS) on occipital cortex extinguishes the effects of exogenous attention but not those of endogenous attention. Together these studies reveal how endogenous and exogenous attention shape perception by altering the processing of basic visual dimensions.

2021 Awards Session >

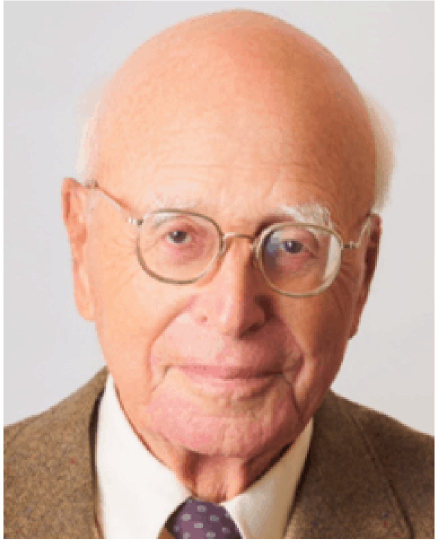
2021 Ken Nakayama Medal for Excellence in Vision Science

Sunday, May 23, 2:30 - 3:30 pm EDT, Talk Room 1-2 Join Zoom Webinar

The Vision Sciences Society is honored to present Gerald Westheimer with the 2021 Ken Nakayama Medal for Excellence in Vision Science.

The Ken Nakayama Medal is in honor of Professor Ken Nakayama's contributions to the Vision Sciences Society, as well as his innovations and excellence to the domain of vision sciences.

The recipient of the Ken Nakayama Medal receives this honor for high-impact work that has made a lasting contribution in vision science in the broadest sense. The nature of this work can be fundamental, clinical or applied.



Gerald Westheimer

Gerald Westheimer received his PhD degree in Physics: Physiological Optics at Ohio State under Glenn Fry in 1953 after completing optometry studies at the Sydney Technical College, a B.Sc. in mathematics and physiology at the University of Sydney and several years of private practice in Sydney, Australia. His post-doctoral education included the Nerve-Muscle Program at Woods Hole under Steven Kuffler, and a year at the Cambridge Physiological Laboratory, where he collaborated with Fergus Campbell and John Robson on the eye's accommodative mechanism and attended E.H. Linfoot's course on Fourier optics. After teaching optics and vision science in the optometry schools successively of Houston, Ohio State and Berkeley he was appointed as Professor of Physiology in Berkeley in 1967 and, when the Department of Molecular and Cell Biology was formed in 1987, as founding Head of its Division of Neurobiology. In 1994 he became Professor of the Graduate School at Berkeley as well as adjunct professor in the Laboratory of Neurobiology at the Rockefeller University, New York.

There are few facets of the visual system that Gerald Westheimer has not been involved in during his long career as active experimentalist, theoretician, scholar of the history of vision science, laboratory head, mentor and sponsor of independent research by post-doctoral and visiting scholars from around the world. His recognitions include election to the Royal Society of London and its Ferrier Lecture, Fellow of the American Academy of Arts and Science, Honorary Member of the Royal Society of NSW, the Tillyer Medal of the Optical Society, Proctor Medal of ARVO, Prentice Medal of the American Academy of Optometry, International von Sallman Prize in Ophthalmology, Barry Collins Medal of the Australian Optometric Association, Glenn Fry Medal of Ohio State University, several honorary degrees and Membership of the Order of Australia.

From his experiences in the optometry clinic Gerald formed an abiding interest in the eye's optics and image formation, resolution and acuity. This led to his progressively deeper fascination with in the spatial sense of the eye in two and three dimensions, stereopsis and ocular motility. He used the research methodologies of optics, psychophysics, alert primate single unit recordings and right from their advent in the 1950's, electronic computers. Rigorous training in mathematics and physics in Sydney enabled him to engage in the areas of systems theory and Fourier optics as they emerged, and to pioneer their application in visual science. Motivated primarily by an interest in and curiosity about human vision rather than the practice of particular scientific disciplines, Gerald concluded that, much as the analysis of visual phenomena should proceed initially by applying the knowledge and principles of the physical sciences, full understanding cannot be reached solely through that route but needs guidance from knowledge derived from observers' awareness. With this approach, he made seminal discoveries in understanding the optics of the eye, binocular vision, spatial vision, eye-movements, learning and visual illusions. One example of his many contributions is his discovery how humans are able to discern small changes in the relative position of a stimulus that are an order of magnitude smaller than the smallest foveal cones in the retina. He termed this remarkable ability "hyperacuity" – a term that is now widely used, and elucidated many of its properties. In this, and in many other ways he shaped the growth of vision research.

Vision science has benefited in lasting ways from Gerald's research discoveries, his acumen, his scientific rigor, and his commitment to getting it right.

Dr. Westheimer will speak during the 2021 Awards session.

2021 Graphics Competition Winner

Sunday, May 23, 2:30 - 3:30 pm EDT, Talk Room 1-2 Join Zoom Webinar

The Vision Sciences Society is pleased to recognize Susanne Stoll as the winner of the V-VSS 2021 Graphics Competition. Her image, shown above and below, is entitled *Global Vision*.

Each year VSS solicits its membership to submit creative visual images related to the field of vision science, the Society, or the VSS meeting. Traditionally, the winning images are featured on the program, abstracts book, signage, and t-shirts. Due to the online format this year, the winning image appears as the banner throughout the VSS 2021 website.

Global Vision

Beauty is in the eye of the beholder and so is the interpretation of *Global Vision*. However, as with most things in life, there is no end product without a mission. As such, *Global Vision* attempts to unify three facets of this year's VSS meeting.

The first facet relates to what we are all striving for, namely understanding vision and how we perceive the ever-changing world around us visually. The second facet is meant to reflect the increased accessibility of this year's gathering due to its virtual nature, with us being distributed all over the globe. The third facet relates to the multi-focal character of the VSS and thus its broad scope, bringing together expertise from various subdomains, including visual psychophysics, visual neuroscience, computational vision, visual cognition, and bordering fields.

Global Vision attempts to feature these facets by dynamically projecting a map of the world onto the right eye of an unknown other standing right in front of you. A static circular searchlight takes snapshots of the map, generating a globe as much as the right iris of the unknown other. The different snapshots can be interpreted to echo an ever-changing world, the different regions the VSS schedules events in (broadly) as well as the subdisciplines the VSS unites. The circular VSS logo hosts a pupil and is thought to represent the left iris. The wavy lines (or sinusoids) demarcate the overall shape of the right and left eye, but can also be seen as a decorative element encapsulating the different facets.

By looking you right in the eyes, *Global Vision* is also meant to ask you quite candidly *what your global vision is*.

Special thanks go to my colleagues and friends in London and Auckland, the Board of Directors, and the VSS organization team for providing constructive feedback on my design idea. I wish everybody a superb and insightful V-VSS 2021.

About Susanne Stoll

Susanne Stoll completed her undergraduate studies in Psychology at the University of Tübingen, followed by an MSc in Mind and Brain at Humboldt University of Berlin. Currently, she is a final year PhD student under the supervision of Dr. Sam Schwarzkopf and Dr. John Greenwood at University College London. Her research uses functional magnetic resonance imaging and population receptive field (pRF) modeling to investigate how perceptual grouping and spatial attention modulate the visual brain's representation of visual information. Susanne also has a keen interest in relating pRF properties to behavior as well as counteracting regression fallacies and probing the validity of analysis procedures in visual neuroimaging and beyond.

2021 Elsevier/*Vision Research* Travel Awards

Sunday, May 23, 2:30 - 3:30 pm EDT, Talk Room 1-2 Join Zoom Webinar

VSS is grateful to **Elsevier/*Vision Research*** for their generous support of this year's virtual meeting. Congratulations to the following VSS student and postdoc members who will receive a V-VSS 2021 Elsevier/*Vision Research* Travel Award, which allows them to present at V-VSS at no additional cost.

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Elsevier/ Vision Research Travel and Young Investigator Awards sponsors VSS 2021

Graduate Students

Etienne Abassi, CNRS, France
Zoha Ahmad, York University, Canada
Michael Allen, University of California, San Diego, US
Alberto Aviles, University of Birmingham, UK
Naila Ayala, University of Waterloo, Canada
Ionela Bara, Bangor University, UK
Asma Braham Chaouche, Université de Montréal, Canada
Cristina Ceja, Northwestern University, US
Shanna H Coop, University of Rochester, US
Sarah Cormiea, Johns Hopkins University, US
Deepa Dhungel, University of Houston, US
Dylan D. Doblar, Massachusetts Institute of Technology, US
Wei Dou, University of California, Santa Cruz, US
Catherine Dowell, University of Southern Mississippi, US
Eric Elmoznino, Johns Hopkins University, US
Simon Faghel-Soubeyrand, Université de Montréal, Canada
Prasakti Tenri Fanyiwi, Newcastle University, UK
Derartu Fite, University of Nevada, Reno, US
Julie Freschl, University of Massachusetts Boston, US
Laura Geurts, Donders Insitute, Radboud University, Netherlands
Jessica Goetz, University of Central Florida, US
Michael Granovetter, Carnegie Mellon University, US
Matthew Groh, MIT, US
Xuanru Guo, Kyushu University, Japan
Chihye Han, Johns Hopkins University, US
Hanna Haponenko, McMaster University, Canada
Geoffrey Harrison, Queen's University, Kingston, Canada
Brittney Hartle, York University, Canada
Shekoofeh Hedayati, The Pennsylvania State University, US
Lukas S. Huber, University of Tübingen, Germany
Polina Iamshchinina, Freie Universität Berlin, Germany
Jessica Ip, University of British Columbia, Canada
Georgin Jacob, Indian Institute of Science, Bangalore, India
Victoria L. Jacoby, University of California, Los Angeles, US
Michael Jigo, New York University, US
Gustavo Juantorena, University of Buenos Aires, Argentina
Jonathan Keefe, University of California, San Diego, US
Sarah Kerns, Wellesley College, US
Vladislav Khvostov, HSE University, Russia
Jessica Knötzele, Institute for Frontier Areas of Psychology and Mental Health (IGPP), Germany
Maria Kon, Purdue University, US

Karolina Krzys, Queen's University, Canada
Menahal Latif, Ryerson University, Canada
Sofia Tkhan Tin Le, NRU HSE, Russia
Kassandra Lee, University of Nevada, Reno, US
Samantha Lee, University of Nevada, Reno, US
Shi Pui Li, Johns Hopkins University, US
Yanjun Li, University of Minnesota, US
Yibiao Liang, University of Massachusetts Boston, US
Ming-Ray Liao, Texas A&M University, US
Y. Isabella Lim, University of Toronto, Canada
Ying Lin, University of Rochester, US
Daniel Lindh, University of Birmingham, UK
Xinyu Liu, University of Minnesota, US
Michael Lopez-Brau, Yale University, US
Jiang Mao, University of Pennsylvania, US
Hannah Masoner, University of Southern Mississippi, US
Kate McKay, The University of Queensland, Australia
M. Fiona Molloy, The Ohio State University, US
Audrey Morrow, University of California, Santa Cruz, US
Kushin Mukherjee, University of Wisconsin-Madison, US
William Narhi-Martinez, The Ohio State University, US
Mahan Nayeb Ghanbar Hosseini, School of Computing, Germany
Sonisha Neupane, Indiana University, US
Irfa Nisar, York University, Canada
Snehal Padhye, Rochester Institute of Technology, US
Ruben Pastilha, Newcastle University, UK
Boris Penaloza, University of Denver, US
Shima Rashidi, University of Melbourne, Australia
Elena Sanz, Universidad Autónoma de Madrid, Spain
Maria Servetnik, KU Leuven, Belgium
Brynn Sherman, Yale University, US
Young Seon Shin, Florida Atlantic University, US
Male Shiva Ram, University of Hyderabad, India
Taylor Simonson, Kansas State University, US
Elisabeth Slifkin, University of Central Florida, US
Maverick Smith, Kansas State University, US
Gaeun Son, University of Toronto, Canada
Mirta Stantic, University of Oxford, UK
Zoe Stearns, University of Rochester, US
Susanne Stoll, University College London, UK
Tyler Surber, The University of Southern Mississippi, US
Duyan Ta, Arizona State University, US
Louisa Talipski, The Australian National University, Australia
Keren Taub, Tel Aviv University, Israel
Xue Teng, York University, Canada
Ehsan Tousi, Western University, Canada
Caitlin Tozios, University of Toronto, Canada
Yanshuai Tu, Arizona State University, US
Zhiyan Wang, Brown University, US
Emma Ward, Freie Universität Berlin, Germany
Phillip Witkowski, University of California, Davis, US

Tristan Yates, Yale University, US
Ling-Qi Zhang, University of Pennsylvania, US
Yuan Zhang, Shanghai University of Sport, China
Ziyao Zhang, Lehigh University, US
Zhetuo Zhao, University of Rochester, US
Lei Zheng, Otto-von-Guericke-Universität Magdeburg, Germany

Postdocs

Doug Addleman, Dartmouth College, US
Emma Alexander, University of California, Berkeley, US
Andrea Bocincova, University of Oxford, UK
Nico Broers, University of Münster, Germany
Antimo Buonocore, University of Tübingen, Germany
Andrew Clement, Texas A&M University, US
Cristina-Ioana Galusca, CNRS Université Grenoble Alpes, France
Haydee Garcia-Lazaro, The Smith-Kettlewell Eye Research Institute, US
Simen Hagen, Université de Lorraine, France
Sabrina Hansmann-Roth, SCALab, France
Christopher Henry, Albert Einstein College of Medicine, US
Zoey Isherwood, University of Nevada, Reno, US
Haiyang Jin, New York University Abu Dhabi, United Arab Emirates
Kohitij Kar, Massachusetts Institute of Technology, US
Mohana Kuppuswamy Parthasarathy, University of Nevada, Reno, US
Justin Lieber, New York University, US
Yong-Jun Lin, New York University, US
Caterina Magri, Johns Hopkins University, US
Mukesh Makwana, Brown University, US
Tyler Manning, University of California, Berkeley, US
Melisa Menceloglu, Brown University, US
Jorge Morales, Johns Hopkins University, US
Timothy Oleskiw, New York University, US
Ori Ossmy, New York University, US
Keiji Ota, New York University, US
Jeongho Park, Harvard University, US
Yujia Peng, University of California, Los Angeles, US
Antonella Pomè, University of Florence, Italy
Cheng Qiu, University of Pennsylvania, US
Fernando Ramírez, NIMH, US
Morteza Rezanejad, University of Toronto, Canada
Garrett Swan, Schepens Eye Research Institute, US
Ömer Dağlar Tanrikulu, University of Iceland, Iceland
Sophia Vinci-Booher, Indiana University, US
Lauren Williams, University of California, San Diego, US

VSS Business Meeting

Monday, May 24, 2:00 - 3:00 pm EDT, Talk Room 1 Join Zoom Webinar

We encourage you to join the VSS Board of Directors for the Annual Business Meeting. During this meeting, the VSS leadership will provide an overview of the Society, including the outlook and priorities for 2022. The Business Meeting is an opportunity for VSS members to ask questions of the VSS Board of Directors and bring up issues of concern to the general membership.

You may send questions before the start of the Business Meeting to vss@visionsciences.org.

Conversations on Open Science

Friday, May 21, 5:00 - 7:00 pm EDT, Talk Room 1 Join Zoom Webinar

Organizer: VSS Student-Postdoc Advisory Committee
Moderator: Björn Jörges, York University
Speakers: Geoffrey Aguirre, Janine Bijsterbosch, Christopher Donkin, Alex Holcombe, and Russell A. Poldrack

Open Science has become an important part of the scientific landscape. Researchers are adopting open practices such as preregistrations and registered reports, open access, and the use of open source software, journals make data and code sharing more and more a desired or even required feature of research publications, and funders are increasingly evaluating the applicants' open science track records along with their scientific proposals. It is therefore more important than ever for all scientists, and particularly for Early Career Researchers, to be able to navigate the Open Science space. For this reason, the Student Postdoc Committee has organized Conversations on Open Science as a means to introduce the VSS community to the basics of Open Science and some current debates.

Conversations on Open Science will start out with a short overview of the most important open practices. The speakers then delve deeper into two topics: preregistration and code and data sharing. We have invited two speakers for each topic: one of them argues in favor, while the other argues against, provides some nuance, or points out limitations. Both parties will first explain their respective perspectives, followed by a joint presentation in which some synthesis or common ground will be reached.

Geoffrey Aguirre

University of Pennsylvania

Geoffrey Aguirre is an Associate Professor of Neurology at the University of Pennsylvania. He has studied the human visual system using functional MRI for nearly twenty-five years, often combining brain imaging with complementary measures of perception and retinal structure. During his career he has contributed to the analytic and inferential foundation of neuroimaging studies. In recent years has worked to adopt and advocate for open-science tools, principally as a means to improve his own research. Contact Geoffrey at **aguirreg@pennmedicine.upenn.edu**.

Janine Bijsterbosch

Washington University School of Medicine

Janine Bijsterbosch has worked in brain imaging since 2007. She is currently Assistant Professor in the Computational Imaging section of the Department of Radiology at Washington University in St Louis. The Personomics Lab headed by Dr. Bijsterbosch aims to understand how brain connectivity patterns differ from one person to the next, by studying the "personalized connectome". Using big data resources such as the Human Connectome Project and UK Biobank, the Personomics Lab adopts cutting edge analysis techniques to study functional connectivity networks and their role in behavior, performance, mental health, disease risk, treatment response, and physiology. Dr. Bijsterbosch is Chair-Elect of the Open Science special interest group as part of the Organization for Human Brain Mapping. In addition, Dr. Bijsterbosch wrote a textbook on functional connectivity analyses, which was published by Oxford University Press in 2017. Contact Janine at **janine.bijsterbosch@wustl.edu**.

Christopher Donkin

UNSW Sydney

Christopher Donkin is a cognitive psychologist at UNSW Sydney. His work tends to rely on a mix of computational modelling and experiments. He is interested in decision-making, memory, models, and metascience. While agreeing that open science is of utmost importance, many long series of conversations with **Aba Szollosi** about how knowledge is created has led to disagreement around the purported benefits of preregistration. Though the content of the talk will be specific to preregistration, the background knowledge underlying these arguments is more carefully laid out here. Contact Chris at **christopher.donkin@gmail.com**.

Alex Holcombe

University of Sydney

Inside his lab, **Alex Holcombe** studies how humans perceive and process visual signals over time, in domains such as motion, position perception, and attentional tracking. Outside of the lab, he has been active in various open science initiatives. He is an associate editor at the journal Meta-psychology and he co-founded the Registered Replication Report article format at Perspectives on Psychological Science in 2014, co-founded the Association for Psychological Science journal Advances in Methods and Practices in Psychological Science in 2018, and served on the founding advisory boards of the preprint server PsyArxiv and the journal PLOS ONE. Contact Alex at **alex.holcombe@sydney.edu.au**.

Russell A. Poldrack

Stanford University

Russell A. Poldrack is the Albert Ray Lang Professor in the Department of Psychology and Professor (by courtesy) of Computer Science at Stanford University, and Director of the Stanford Center for Reproducible Neuroscience. His research uses neuroimaging to understand the brain systems underlying decision making and executive function. His lab is also engaged in the development of neuroinformatics tools to help improve the reproducibility and transparency of neuroscience, including the Openneuro.org and Neurovault.org data sharing projects and the Cognitive Atlas ontology. Contact Russ at **poldrack@stanford.edu**.

Björn Jörges

York University

Björn Jörges studies the role of prediction for visual perception, as well as visuo-vestibular integration for the perception of object motion and self-motion. Beyond these topics, he also aspires to make science better, i.e., more diverse, more transparent and more robust. After finishing his PhD in Barcelona on the role of a strong earth gravity prior for perception and action, he started a Postdoc in the Multisensory Integration Lab at York University, where he currently investigates how the perception of self-motion changes in response to microgravity. Contact Björn at **bjoerges@yorku.ca**.

US Funding Workshop

Saturday, May 22, 12:00 - 1:00 pm EDT, Sea Turtle Join Zoom Webinar

Moderator: **Ruth Rosenholtz**

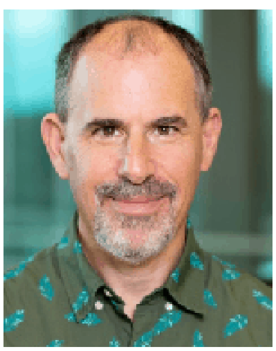
Discussants: **Joeanna Arthur**, **Todd Horowitz**, **Michael Hout**, and **Cheri Wiggs**

You have a great research idea, but you need money to make it happen. You need to write a grant. This workshop will address various funding mechanisms for vision research. Our panelists will discuss their organization's interests and priorities, and give insight into the inner workings of their extramural research programs. There will be time for your questions.

Joeanna Arthur

National Geospatial-Intelligence Agency

Joeanna Arthur, Ph.D., is a Supervisory Research & Development Scientist and Senior Staff Scientist in the Predictive Analytics Research Group at the National-Geospatial Intelligence Agency (NGA) where she leads a transdisciplinary team of scientists advancing Geospatial Science and enhancing analytic tradecraft. She also serves as the agency's Human Research Protection Official. Prior government assignments include Chief of Research(FBI/HIG), Lead Behavioral Scientist/Psychologist (DIA), Program Manager and Operational Test & Evaluation Lead (NGA). Her past and current research areas span the fields of cognitive neuroscience, operational psychology, human-system integration, human performance optimization, intelligence interviewing, research ethics, and applied social science. She received her doctorate degree in Psychology/Cognitive Neuroscience from the George Washington University (Washington, DC) and completed a post-doctoral research fellowship in the Department of Otolaryngology- Head and Neck Surgery at the John Hopkins University School of Medicine (Baltimore, MD). Dr. Arthur is one of the Intelligence Community's first recipients of the Presidential Early Career Award in Science and Engineering (PECASE 2012, White House Office of Science and Technology Policy).



Todd Horowitz

National Cancer Institute

Todd Horowitz, Ph.D., is a Program Director in the Behavioral Research Program's (BRP) Basic Biobehavioral and Psychological Sciences Branch (BBPSB), located in the Division of Cancer Control and Population Sciences (DCCPS) at the National Cancer Institute (NCI). Dr. Horowitz earned his doctorate in Cognitive Psychology at the University of California, Berkeley in 1995. Prior to joining NCI, he was Assistant Professor of Ophthalmology at Harvard Medical School and Associate Director of the Visual Attention Laboratory at Brigham and Women's Hospital. He has published more than 70 peer-reviewed research papers in vision science and cognitive psychology. His research interests include attention, perception, medical image interpretation, cancer-related cognitive impairments, sleep, and circadian rhythms.

Michael Hout

National Science Foundation

Michael Hout, Ph.D., is a Program Director for Perception, Action, and Cognition in the Social, Behavioral, and Economic Sciences directorate (in the Behavioral and Cognitive Sciences division) of the National Science Foundation. He received his undergraduate degree at the University of Pittsburgh and his masters and doctoral degrees from Arizona State University. He is a rotating Program Director on professional leave from New Mexico State University where he runs a lab in the Psychology Department and co-directs an interdisciplinary virtual and augmented reality lab as well. Prior to joining the NSF he was a conference organizer for the Object Perception, Attention, and Memory meeting and was an Associate Editor at

Attention, Perception, and Psychophysics. His research focuses primarily on visual cognition (including visual search, attention, and eye movements), spanning both basic theoretical research and applied scenarios such as professional medical/security screening, and search and rescue.

Cheri Wiggs

National Eye Institute

Cheri Wiggs, Ph.D., serves as a Program Director at the National Eye Institute (of the National Institutes of Health). She oversees extramural funding through three programs — Perception & Psychophysics, Myopia & Refractive Errors, and Low Vision & Blindness Rehabilitation. She received her PhD from Georgetown University in 1991 and came to the NIH as a researcher in the Laboratory of Brain and Cognition. She made her jump to the administrative side of science in 1998 as a Scientific Review Officer. She currently represents the NEI on several trans-NIH coordinating committees (including BRAIN, Behavioral and Social Sciences Research, Medical Rehabilitation Research) and was appointed to the NEI Director's Audacious Goals Initiative Working Group.

Ruth Rosenholtz

MIT

Ruth Rosenholtz is a Principal Research Scientist in the Department of Brain & Cognitive Sciences at the Massachusetts Institute of Technology. She studies a wide range of visual phenomena, as well as applied vision, using a mix of behavioral methods and computational modeling. Her main research topics include attention and visual search; perceptual organization; and peripheral vision. She is a fellow of the APS, an associate editor for the Journal Vision, and a VSS board member. Her funding sources have included NSF, NIH, Toyota, and Ford.

Peer Review of NIH NRSA Fellowship Proposals

Tuesday, May 25, 5:00 - 5:30 pm EDT, Sea Turtle Join Zoom Webinar

Speaker: **Cibu Thomas**

The objective of this session is to provide the principal investigators and their sponsors an overview about the process by which peer review of predoctoral and postdoctoral NRSA proposals is implemented by the NIH Center for Scientific Review.

Cibu Thomas

National Institutes of Health

Dr. Cibu Thomas earned his M.S. in Applied Cognition and Neuroscience from the University of Texas at Dallas, and his Ph.D. in Psychology from Carnegie Mellon University. After postdoctoral training at the Athinoula A. Martinos Center for Biomedical Imaging at Massachusetts General Hospital, Harvard Medical School, he served as a Research Fellow at the Center for Neuroscience and Regenerative Medicine. He then served as a Staff Scientist for the Section on Learning and Plasticity in the Laboratory of Brain and Cognition at the National Institute of Mental Health, where his research focused on elucidating the principles governing brain plasticity and its relation to behavior using multimodal MRI and psychophysics. He is currently the scientific review officer for the NIH NRSA Fellowships study section F02B, which manages the scientific review of applications proposing training that is focused on understanding normal sensory (both auditory and visual), motor or sensorimotor function as well as disorders of cognitive, sensory, perceptual and motor development.

No advance sign-up is required to attend this event.

Connect with Industry

Wednesday, May 26, 12:00 - 1:00 pm EDT, Sandpiper **Join Zoom Webinar**

To reflect the range of interests and career goals of VSS attendees, we are pleased to offer our popular **Connect with Industry** event.

This is an opportunity for our members to interact with representatives of industry and government agencies. Representatives from a range of organizations and industries will be present to discuss opportunities for vision scientists in their companies and to answer questions about collaborating with, and working within, their organizations.

Representatives from Apple, Exponent, Facebook Reality Labs, Magic Leap, Microsoft, NIH, Vivid Vision, and VPixx Technologies will be attending.

No advance sign-up is required to attend this event.

Meet the Professors

Friday, May 21, 8:00 - 9:00 pm EDT, Sandpiper Join Zoom Webinar

A session is also scheduled for **Tuesday**.

Students and postdocs are invited to the fifth annual **Meet the Professors** event. This is an opportunity for a free-wheeling, open-ended discussion with members of the VSS Board and other professors. You might chat about science, the annual meeting, building a career, or whatever comes up.

Each one-hour session will be divided into two 30-minute Zoom breakouts so that participants will have the opportunity to interact with two different professors within each session. Students may attend both Friday and **Tuesday** session.

Please **Log In** to access Registration form.

Professors

Members of the VSS Board are indicated with an asterisk*, in case you have a specific interest in talking to a member of the Board.

Edward Adelson (MIT) is interested in vision and touch in humans and robots. *(Recipient of the 2020 Ken Nakayama Medal for Excellence in Vision Science)*

Geoffrey Boynton* (University of Washington) studies the effects of spatial, featural and divided attention on the human brain and behavior, and develops models that simulate the experience of patients with visual prosthetics.

Hakwan Lau (Riken Institute) studies the psychophysics of conscious perception, attention, metacognition, as well as their neural mechanisms. He has previously worked in both Europe and the United States.

Nestor Matthews (Denison University) studies perceptual learning and perceptual expertise in spatial and temporal aspects of vision and attention.

Ipek Oruc (University of British Columbia, Vancouver) studies form vision with an emphasis on face and object recognition using various methodologies ranging from visual psychophysics, neuroimaging to machine learning.

Joo-Hyun Song (Brown University) studies how perception and cognition seamlessly interact with visually-guided action in complex environments.

Miriam Spering (University of British Columbia, Vancouver) studies how vision and eye movements interact and what eye movements can reveal about decision making processes in health and disease.

Gerald Westheimer (UC Berkeley, retired) studied spatial vision and in particular the optical and neural factors involved in resolution and visual and stereoscopic acuity. *(Recipient of the 2021 Ken Nakayama Medal for Excellence in Vision Science)*

Meet the Professors

Tuesday, May 25, 12:00 - 1:00 pm EDT, Sandpiper Join Zoom Webinar

A session is also scheduled for **Friday**.

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Please **Log In** to access Registration form.

Professors

Members of the VSS Board are indicated with an asterisk*, in case you have a specific interest in talking to a member of the Board.

Marlene Behrmann (Carnegie Mellon University) studies high-level vision in normal and brain-damaged (e.g. hemispherectomy) patients to elucidate the nature of visual computations, their topography, and the opportunity for plasticity. *(Recipient of the 2020 Davida Teller Award)*

Timothy Brady (University of California, San Diego) studies visual working memory, visual long-term memory, ensemble perception, scene perception, visual learning, and how all of these things intersect, with a focus on behavioral approaches and computational models. *(Recipient of the 2020 VSS Young Investigator Award)*

Karla Evans (University of York) studies visual attention and memory and cross modal perception using a variety of methods that allow for translating basic research findings to address real-world questions.

Chaz Firestone (Johns Hopkins University) studies how visual perception interacts (and fails to interact) with higher-level cognition, as well as how vision science interacts (and could better interact) with neighboring fields, including artificial intelligence, developmental psychology, and the philosophy of perception.

Michelle Greene (Bates College) studies the time course of perceiving scene and object categories.

Wei-Ji Ma (New York University) studies a wide diversity of topics in perception and cognition with a computational angle. Recent interests include thinking ahead in complex games, suboptimal inference, and visual working memory.

Maria Olkkonen (Durham University & University of Helsinki) studies color perception and color constancy, in particular how statistical color knowledge is learned and used to estimate object color.

Martina Poletti (University of Rochester) studies how attention and eye movements contribute to visual perception and how they are controlled at the foveal scale. *(Recipient of the 2021 VSS Young Investigator Award)*

Fabian Soto (Florida International University, Miami) studies how existing visual representations shape the mechanisms of learning and generalization that are deployed in a particular task, and how in turn learning modifies visual representations. His research combines psychophysics, computational modeling, and neuroimaging.

Viola Störmer (Dartmouth College) studies spatial and feature-based attention, how attention shapes perception, cross-modal interactions between audition and vision, and the capacity and structure of visual working memory. Her research draws on a variety of methods, including psychophysics, experimental psychology, and human electrophysiology (EEG).

Maarten Wijntjes (Delft University of Technology) studies the depiction and perception of material properties in the context of visual communication design, digital humanities, and the arts.

Jonathan Winawer (New York University) studies how spatial and temporal visual information is encoded in the nervous system, with an emphasis on linking psychophysical measurements to anatomy and models of neural processing.

Virtual Coffee Break

Virtual coffee breaks are scheduled throughout V-VSS. Like coffee breaks at the in-person meetings, the virtual coffee breaks offer attendees an opportunity for social interaction, networking, and connecting with colleagues.

Grab a cup of coffee and meet in the **Gather.Town** Courtyard, Lobby, or Beach!!

The Student-Postdoc Advisory Committee is conducting organized networking events held in the Gator Room during the coffee break immediately following each talk session. During these informal get-togethers, students and postdocs can join discussions dedicated to the previous talk session or just chat over a virtual coffee and enjoy a board game.

Student-Postdoc Networking Events

During the entirety of V-VSS 2021, the Student-Postdoc Advisory Committee (SPC) will be hosting a space in Gather.Town dedicated to student-postdoc networking. Students and postdocs are encouraged to visit the Gator room throughout the meeting where they can arrange to meet up with friends, meet new ones, play games, or join in discussions.

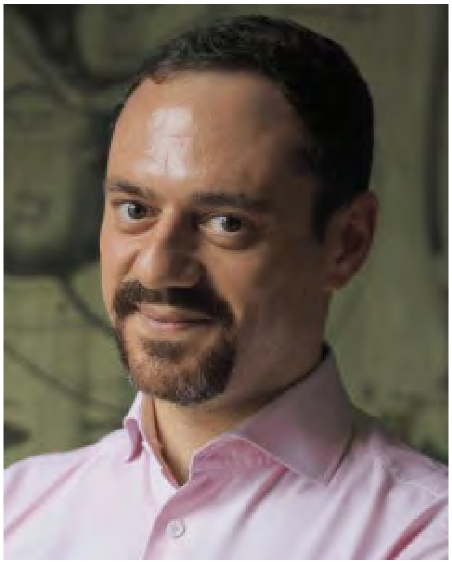
There will also be organized networking events held in this space during the coffee break immediately following each talk session. During these informal networking events, students and postdocs are encouraged to stop by the Gator room where they can join discussions dedicated to the previous talk sessions or just chat over a virtual coffee and enjoy a board game. Members of the current and future Student-Postdoc Advisory Committee will also be there, so this is a great opportunity to get to know your VSS representatives.

Public Lecture

Tuesday, May 25, 12:00 - 1:00 pm EDT, Zoom Room **Join Zoom Webinar**

We welcome members of the general public to attend. There is no charge. Space is limited.

The annual public lecture represents the mission and commitment of the Vision Sciences Society to promote progress in understanding vision and its relation to cognition, action and the brain. As scientists we are obliged to communicate the results of our work, not only to our professional colleagues, but also to the broader public. This lecture is part of our effort to give back to the community that supports us.



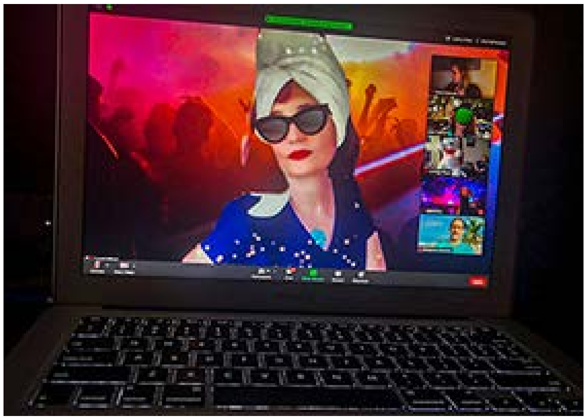
Roland Fleming, PhD

Justus Liebig University Giessen, Germany

Roland Fleming is an interdisciplinary researcher who investigates how the brain allows us to see the physical properties of objects. He studied at Oxford and MIT and has worked at the Max Planck Institute for Biological Cybernetics. He is currently the Kurt Koffka Professor of Experimental Psychology at the University of Giessen in Germany. He has won a number of prizes, including the Elsevier-Vision Sciences Society Young Investigator Award in 2013.

Big Data and the Brain: How we Learn to See 'Stuff' from Lots and Lots of Examples

How does the brain learn to see? When we are newborn, we can hardly recognize anything by sight, yet by the time we are adults we have exquisite visual and motor skills. Without touching objects we can make an incredible range of visual judgments about their properties. We can see an object's 3D shape, work out whether it is soft or hard, fragile or durable, and anticipate how it is likely to respond if we try to squeeze it. Somehow, by looking at and interacting with lots of 'Stuff', we learn how to recognize it. In this talk, vision scientist Roland Fleming will discuss some of the challenges that objects and materials pose to the visual system, and describe some of the amazing progress researchers have recently made in using deep learning to build artificial visual systems that can see like humans.



Club Vision

Wednesday, May 26, 4:00 - 6:00 pm EDT, Beach Join Zoom Webinar

Join us at the end the conference for our second annual Zoom-based dance party, where we will celebrate making it through a challenging year. Bring your glow sticks, disco lights, creative zoom backgrounds, and pent-up energy.

In addition to the dance floor (in the main Zoom room), you can catch up with friends at the beach in Gather.Town.

Organized by Martin Rolfs, Alex White, & Stefan van der Stigchel.

Symposia

Early Processing of Foveal Vision

Friday, May 21, 8:00 - 10:00 am EDT, Talk Room 1 Join Zoom Webinar

Organizers: Lisa Ostrin[1], David Brainard[2], Lynne Kiorpes[3]; [1]University of Houston College of Optometry, [2]University of Pennsylvania, [3]New York University

This year's biennial ARVO at VSS symposium focuses on early stages of visual processing at the fovea. Speakers will present recent work related to optical, vascular, and neural factors contributing to vision, as assessed with advanced imaging techniques. The work presented in this session encompasses clinical and translational research topics, and speakers will discuss normal and diseased conditions.

Wait for it: 20 years of temporal orienting

Friday, May 21, 8:00 - 10:00 am EDT, Talk Room 2 Join Zoom Webinar

Organizers: Nir Shalev[1,2,3], Anna Christina (Kia) Nobre[1,2,3]; [1]Department of Experimental Psychology, University of Oxford, [2]Wellcome Centre for Integrative Neuroscience, University of Oxford, [3]Oxford Centre for Human Brain Activity, University of Oxford

Time is an essential dimension framing our behaviour. In considering adaptive behaviour in dynamic environments, it is essential to consider how our psychological and neural systems pick up on temporal regularities to prepare for events unfolding over time. The last two decades have witnessed a renaissance of interest in understanding how we orient attention in time to anticipate relevant moments. New experimental approaches have proliferated and demonstrated how we derive and utilise recurring temporal rhythms, associations, probabilities, and sequences to enhance perception. We bring together researchers from across the globe exploring the fourth dimension of selective attention with complementary approaches.

What we learn about the visual system by studying non-human primates: Past, present and future

Friday, May 21, 2:30 - 4:30 pm EDT, Talk Room 1 Join Zoom Webinar

Organizers: Rich Krauzlis[1], Michele Basso[2]; [1]National Eye Institute, [2]Brain Research Institute, UCLA

Non-human primates (NHPs) are the premier animal model for understanding the brain circuits and neuronal properties that accomplish vision. This symposium will take a "look back" at what we have learned about vision over the past 20 years by studying NHPs, and also "look forward" to the emerging opportunities provided by new techniques and approaches. The 20th anniversary of VSS is the ideal occasion to present this overview of NHP research to the general VSS membership, with the broader goal of promoting increased dialogue and collaboration between NHP and non-NHP vision researchers.

What has the past 20 years of neuroimaging taught us about human vision and where do we go from here?

Friday, May 21, 2:30 - 4:30 pm EDT, Talk Room 2 Join Zoom Webinar

Organizers: Susan Wardle[1], Chris Baker[1]; [1]National Institutes of Health

Over the past 20 years, neuroimaging methods have become increasingly popular for studying the neural mechanisms of vision in the human brain. To celebrate 20 years of VSS this symposium will focus on the contribution that brain imaging techniques have made to our field of vision science. The aim is to provide both a historical context and an overview of current trends for the role of neuroimaging in vision science. This will lead to informed discussion about what future directions will prove most fruitful for answering fundamental questions in vision science.

Feedforward & Recurrent Streams in Visual Perception

Monday, May 24, 9:30 - 11:30 am EDT, Talk Room 1 Join Zoom Webinar

Organizers: Shaul Hochstein[1], Merav Ahissar[2]; [1]Life Sciences, Hebrew University, Jerusalem, [2]Psychology, Hebrew University, Jerusalem

Interactions of bottom-up and top-down mechanisms in visual perception are heatedly debated to this day. The aim of the proposed symposium is to review the history, progress, and prospects of our understanding of the roles of feedforward and recurrent processing streams. Where and how does top-down influence kick in? Is it off-line, as suggested by some deep-learning networks? is it an essential aspect governing bottom-up flow at every stage, as in predictive processing? We shall critically consider the continued endurance of these models, their meshing with current state-of-the-art theories and accumulating evidence, and, most importantly, the outlook for future understanding.

What's new in visual development?

Monday, May 24, 9:30 - 11:30 am EDT, Talk Room 2 Join Zoom Webinar

Organizers: Oliver Braddick[1], Janette Atkinson[2]; [1]University of Oxford, [2]University College London

Since 2000, visual developmental science has advanced beyond defining how and when basic visual functions emerge during childhood. Advances in structural MRI, fMRI and near-infrared spectroscopy have identified localised visual brain networks even in early months of life, including networks identifying objects and faces. Newly refined eye tracking has examined how oculomotor function relates to the effects of visual experience underlying strabismus and amblyopia. New evidence has allowed us to model developing visuocognitive processes such as decision-making and attention. This symposium illustrates how such advances, ideas and challenges enhance understanding of visual development, including infants and children with developmental disorders.

Early Processing of Foveal Vision

Friday, May 21, 8:00 - 10:00 am EDT, Talk Room 1 **Join Zoom Webinar**

Organizers: Lisa Ostrin[1], David Brainard[2], Lynne Kiorpes[3]; [1]University of Houston College of Optometry, [2]University of Pennsylvania, [3]New York University
Speakers: Susana Marcos, Brian Vohnsen, Ann Elsner, and Juliette E. McGregor

This year's biennial ARVO at VSS symposium focuses on early stages of visual processing at the fovea. Speakers will present recent work related to optical, vascular, and neural factors contributing to vision, as assessed with advanced imaging techniques. The work presented in this session encompasses clinical and translational research topics, and speakers will discuss normal and diseased conditions.

Foveal aberrations and the impact on vision

Susana Marcos[1]; [1]Institute of Optics, CSIC

Optical aberrations degrade the quality of images projected on the retina. The magnitude and orientation of the optical aberrations vary dramatically across individuals. Changes also occur with processes such as accommodation, and aging, and also with corneal and lens disease and surgery. Certain corrections such as multifocal lenses for presbyopia modify the aberration pattern to create simultaneous vision or extended depth-of-focus. Ocular aberrometers have made their way into the clinical practice. Besides, quantitative 3-D anterior segment imaging has allowed quantifying the morphology and alignment of the cornea and lens, linking ocular geometry and aberrations through custom eye models, and shedding light on the factors contributing to the optical degradation. However, perceived vision is affected by the eye's aberrations in more ways than those purely predicted by optics, as the eye appears to be adapted to the magnitude and orientation of its own optical blur. Studies using Adaptive Optics, not only reveal the impact of manipulating the optical aberrations on vision, but also that the neural code for blur is driven by subject's own aberrations.

The integrated Stiles-Crawford effect: understanding the role of pupil size and outer-segment length in foveal vision

Brian Vohnsen[1]; [1]Advanced Optical Imaging Group, School of Physics, University College Dublin, Ireland

The Stiles-Crawford effect of the first kind (SCE-I) describes a psychophysical change in perceived brightness related to the angle of incidence of a ray of light onto the retina. The effect is commonly explained as being due to angular-dependent waveguiding by foveal cones, yet the SCE-I is largely absent from similar-shaped rods suggesting that a different mechanism than waveguiding is at play. To examine this, we have devised a flickering pupil method that directly measures the integrated SCE-I for normal pupil sizes in normal vision rather than relying on mathematical integration of the standard SCE-I function as determined with Maxwellian light. Our results show that the measured effective visibility for normal foveal vision is related to visual pigment density in the three-dimensional retina rather than waveguiding. We confirm the experimental findings with a numerical absorption model using Beer-Lambert's law for the visual pigments.

Structure of cones and microvasculature in healthy and diseased eyes

Ann Elsner[1]; [1]Indiana University School of Optometry

There are large differences in the distribution of cones in the living human retina, with the density at the fovea varying more than with greater eccentricities. The size and shape of the foveal avascular zone also varies across individuals, and distances between capillaries can be greatly enlarged in disease. While diseases such as age-related macular degeneration and diabetes impact greatly on both cones and retinal vessels, some cones can survive for decades although their distributions become more irregular. Surprisingly, in some diseased eyes, cone density at retinal locations outside those most compromised can exceed cone density for control subjects.

Imaging of calcium indicators in retinal ganglion cells for understanding foveal function

Juliette E. McGregor[1]; [1]Centre for Visual Science, University of Rochester

The fovea mediates much of our conscious visual perception but is a delicate retinal structure that is difficult to investigate physiologically using traditional approaches. By expressing the calcium indicator protein GCaMP6s in retinal ganglion cells (RGCs) of the living primate we can optically read out foveal RGC activity in response to visual stimuli presented to the intact eye. Pairing this with adaptive optics ophthalmoscopy it is possible to both present highly stabilized visual stimuli to the fovea and read out retinal activity on a cellular scale in the living animal. This approach has allowed us to map the functional architecture of the fovea at the retinal level and to classify RGCs in vivo based on their responses to chromatic stimuli. Recently we have used this platform as a pre-clinical testbed to demonstrate successful restoration of foveal RGC responses following optogenetic therapy.

< Symposia

Wait for it: 20 years of temporal orienting

Friday, May 21, 8:00 - 10:00 am EDT, Talk Room 2 Join Zoom Webinar

Organizers: Nir Shalev[1,2,3], Anna Christina (Kia) Nobre[1,2,3]; [1]Department of Experimental Psychology, University of Oxford, [2]Wellcome Centre for Integrative Neuroscience, University of Oxford, [3]Oxford Centre for Human Brain Activity, University of Oxford
Speakers: Jennifer Coull, Rachel Denison, Shlomit Yuval-Greenberg, Nir Shalev, Sander Los, and Assaf Breska

The study of temporal preparation in guiding behaviour adaptively and proactively has long roots, traceable at least as far back as Wundt (1887). Additional forays into exploring the temporal dimension of anticipatory attention resurfaced during the early years of cognitive psychology. But, the field of selective temporal attention has undoubtedly blossomed in the last twenty years. In 1998, Coull and Nobre introduced a temporal analogue of the visual spatial orienting paradigm (Posner, 1980), demonstrating sizeable and reproducible effects of temporal orienting, as well as ushering in studies to study its neural systems and mechanisms. The studies built on seminal psychological demonstrations of auditory perceptual facilitation by temporal rhythms (Jones, 1976).

Over the ensuing years, investigating ‘when we attend’ has become increasingly mainstay. Today we recognise that our psychological and neural systems extract temporal information from recurring temporal rhythms, associations, probabilities, and sequences to enhance perception in the various modalities as well as across them. Sophisticated experimental designs have been developed, and various approaches have been applied to investigate the principles of selective temporal attention. Are there dedicated systems for anticipating events in time leading to a common set of modulatory functions? Or, are mechanisms for temporal orienting embedded within task-specific systems and dependent on the nature of the available temporal regularities (e.g., rhythms or associations).

In the following symposium, we illustrate contemporary research on selective temporal attention by bringing together researchers from across the globe and using complementary approaches. Across the presentations, researchers explore the roles of temporal rhythms, associations, probabilities, and sequences using psychophysics, eye movements, neural measurements, neuropsychology, developmental psychology, and theoretical models. In a brief introduction, Coull and Nobre will comment on the context of their initial temporal orienting studies and on the major strands and developments in the field.

The first research presentation by Rachel Denison (with Marisa Carrasco) will introduce behavioural and neurophysiological studies demonstrating the selective nature of temporal attention and its relative costs and benefits to performance. The second presentation by Shlomit Yuval-Greenberg will show how anticipatory temporal attention influences oculomotor behaviour, with converging evidence from saccades, micro-saccades, and eye-blinks. The third presentation by Nir Shalev (with Sage Boettcher) will show how selective temporal attention generalises to dynamic and extended visual search contexts, picking up on learned conditional probabilities to guide perception and eye movement in adults and in children. The fourth presentation by Assaf Breska will provide evidence for a double dissociation between temporal attention based on temporal rhythms vs. associations by comparing performance of individuals with lesions in the cerebellum vs. basal ganglia. The final presentation by Sander Los will introduce a theoretical and computational model that proposes to account to various effects of temporal orienting across multiple time spans – from between successive trials to across contexts.

A panel discussion will follow, to consider present and forthcoming research challenges and opportunities. In addition to considering current issues in selective temporal attention, our aim is to lure our static colleagues into the temporal dimension.

20 years of temporal orienting: an introduction

Jennifer Coull[1,2], Anna Christina Nobre[3,4,5]; [1]Aix-Marseille Universite, France, [2]French National Center for Scientific Research (CNRS), [3]Department of Experimental Psychology, University of Oxford, [4]Wellcome Centre for Integrative Neuroscience, University of Oxford, [5]Oxford Centre for Human Brain Activity, University of Oxford

In a brief introduction to the symposium, we will spell out the main questions and issues framing cognitive neuroscience studies of attention when we conducted our first temporal orienting combining behavioural methods with PET, fMRI, and ERPS. We will reflect on the strands of research at the time which helped guide our thinking and interpretation of results; and then consider the rich, varied, and many ways in which the temporal attention field has evolved into its exciting, dynamic, and multifaceted guise.

The dynamics of temporal attention

Rachel Denison[1], Marisa Carrasco[1]; [1]Department of Psychology, New York University

Selection is the hallmark of attention: processing improves for attended items but is relatively impaired for unattended items. It is well known that visual spatial attention changes sensory signals and perception in this selective fashion. In the research we will present, we asked whether and how attentional selection happens across time. Specifically, we investigated voluntary temporal attention, the goal-driven prioritization of visual information at specific points in time. First, our experiments revealed that voluntary temporal attention is selective, resulting in perceptual tradeoffs across time. Perceptual sensitivity increased at attended times and decreased at unattended times, relative to a neutral condition in which observers were instructed to sustain attention. Temporal attention changed the precision of orientation estimates, as opposed to an all-or-none process, and it was similarly effective at different visual field locations (fovea, horizontal meridian, vertical meridian). Second, we measured microsaccades and found that directing voluntary temporal attention increases the stability of the eyes in anticipation of a brief, attended stimulus, improving perception. Attention affected microsaccade dynamics even for perfectly predictable stimuli. Precisely timed gaze stabilization can therefore be an overt correlate of the allocation of temporal attention. Third, we developed a computational model of dynamic attention, which incorporates normalization and dynamic gain control, and accounts for the time-course of perceptual tradeoffs. Altogether, this research shows how voluntary temporal attention increases perceptual sensitivity at behaviorally relevant times, and helps manage inherent limits in visual processing across short time intervals. This research advances our understanding of attention as a dynamic process.

Oculomotor inhibition as a correlate of temporal orienting

Shlomit Yuval-Greenberg[1,2], Noam Tal[1], Dekel Abeles[1]; [1]School of Psychological Sciences, Tel-Aviv University, [2]Sagol School of Neuroscience, Tel-Aviv University

Temporal orienting in humans is typically assessed by measuring classical behavioral measurements, such as reaction times (RTs) and accuracy-rates, and by examining electrophysiological responses. But these methods have some disadvantages: RTs and accuracy-rates provide only retrospective estimates of temporal orientation, and electrophysiological markers are often difficult to interpret. Fixational eye movements, such as microsaccades, occur continuously and involuntarily even when observers attempt to suppress them by holding steady fixation. These continuous eye movements can provide reliable and interpretable information on fluctuations of cognitive states across time, including those that are related to temporal orienting. In a series of studies, we show that temporal orienting is associated with the inhibition of oculomotor behaviors, including saccades, microsaccades and eye-blinks. First, we show that eye movements are inhibited prior to predictable visual targets. This effect was found for targets that were anticipated either because they were embedded in a rhythmic stream of stimulation or because they were preceded by an informative temporal cue. Second, we show that this effect is not specific to the visual modality but is present also for temporal orienting in the auditory modality. Last, we show that the oculomotor inhibition effect of temporal orienting is related to the construction of expectations and not to the estimation of interval duration, and also that it reflects a local trial-by-trial anticipation rather than a global arousal state. We conclude that pre-target inhibition of oculomotor behaviors is a reliable correlate of temporal orienting processes of various types and modalities.

Spatial-temporal predictions in a dynamic visual search

Nir Shalev[1,2,3], Sage Boettcher[1,2,3], Anna Christina Nobre[1,2,3]; [1]Department of Experimental Psychology, University of Oxford, [2]Wellcome Centre for Integrative Neuroscience, University of Oxford, [3]Oxford Centre for Human Brain Activity, University of Oxford

Our environment contains many regularities that allow the anticipation of upcoming events. Waiting for a traffic light to change, an elevator to arrive, or using a toaster: all contain temporal ‘rules’ that can be learned and used to improve performance. We investigated the guidance of spatial attention based on spatial-temporal associations using a dynamic variation of a visual search task. On each trial, individuals searched for eight targets among distractors, all fading in and out of the display at different locations and times. The screen was split into four distinct quadrants. Crucially, we rendered four targets predictable by presenting them repeatedly in the same quadrants and times throughout the task. The other four targets were randomly distributed in their locations and onsets. At the first part of our talk, we will show that participants are faster and more accurate in detecting predictable targets. We identify this benefit when testing both young adults (age 18-30), and in a cohort of young children (age 5-6). At the second part of the talk, we will present a further inquiry about the source of the behavioural benefit, contrasting sequential-priming vs. memory guidance. We do so by introducing two more task variations: one in which the onsets and locations of all targets occasionally repeated in successive trials; and one in which the trial pattern was occasionally violated. The results suggest that both factors, i.e., priming and memory, provide a useful source for guiding attention.

Is temporal orienting a voluntary and controlled process?

Sander Los[1], Martijn Meeter[1], Wouter Kruijne[2]; [1]Vrije Universiteit Amsterdam, [2]University of Groningen

Temporal orienting involves the allocation of attentional resources to future points in time to facilitate the processing of an expected target stimulus. To examine temporal orienting, studies have varied the foreperiod between a warning stimulus and a target stimulus, with a cue specifying the duration of the foreperiod at the start of each trial with high validity (typically 80%). It has invariably been found that the validity of the cue has a substantial behavioral effect (typically expressed in reaction times) on short-foreperiod trials but not on long-foreperiod trials. The standard explanation of this asymmetry starts with the idea that, at the start of each trial, the participant voluntarily aligns the focus of attention with the moment specified by the cue. On short foreperiod trials, this policy leads to an effect of cue validity, reflecting differential temporal orienting. By contrast, on long-foreperiod trials, an initially incorrect early focus of attention (induced by an invalid cue) will be discovered during the ongoing foreperiod, allowing re-orienting toward a later point in time, thus preventing behavioral costs. In this presentation, we challenge this view. Starting from our recent multiple trace theory of temporal preparation (MTP), we developed an alternative explanation based on the formation of associations between the specific cues and foreperiods. We will show that MTP accounts naturally for the typical findings in temporal orienting without recourse to voluntary and controlled processes. We will discuss initial data that serve to distinguish between the standard view and the view derived from MTP.

Distinct mechanisms of rhythm- and interval-based attention shifting in time

Assaf Breska[1]; [1]Department of Psychology, University of California, Berkeley, [2]Helen Wills Neuroscience Institute, University of California, Berkeley

A fundamental principle of brain function is the use of temporal regularities to predict the timing of upcoming events and proactively allocate attention in time accordingly. Historically, predictions in rhythmic streams were explained by oscillatory entrainment models, whereas predictions formed based on associations between cues and isolated interval were explained by dedicated interval timing mechanisms. A fundamental question is whether predictions in these two contexts are indeed mediated by distinct mechanisms, or whether both rely on a single mechanism. I will present a series of studies that combined behavioral, electrophysiological, neuropsychological and computational approached to investigate the cognitive and neural architecture of rhythm- and interval-based predictions. I will first show that temporal predictions in both contexts similarly modulate behavior and anticipatory neural dynamics measured by EEG such as ramping activity, as well as phase-locking of delta-band activity, previously taken as signature of oscillatory entrainment. Second, I will show that cerebellar degeneration patients were impaired in forming temporal predictions based on isolated intervals but not based on rhythms, while Parkinson's disease patients showed the reverse pattern. Finally, I will demonstrate that cerebellar degeneration patients show impaired temporal adjustment of ramping activity and delta-band phase-locking, as well as timed suppression of beta-band activity during interval-based prediction. Using computational modelling, I will identify the aspects of neural dynamics that prevail in rhythm-based prediction despite impaired interval-based prediction. To conclude, I will discuss implications for rhythmic entrainment and interval timing models, and the role of subcortical structures in temporal prediction and attention.

< Symposia

What we learn about the visual system by studying non-human primates: Past, present and future

Friday, May 21, 2:30 - 4:30 pm EDT, Talk Room 1 Join Zoom Webinar

Organizers: Rich Krauzlis[1], Michele Basso[2]; [1]National Eye Institute, [2]Brain Research Institute, UCLA
Speakers: Ziad Hafed, Farran Briggs, Jude Mitchell, Marlene Cohen, Nicole Rust, and Bevil Conway

The symposium includes six highly regarded mid-career and junior investigators (Ziad Hafed, Farran Briggs, Jude Mitchell, Marlene Cohen, Nicole Rust, Bevil Conway) who use NHPs to study a range of topics (e.g., attention, eye movements, object and color perception) of interest to the VSS membership.

Ziad Hafed will review how an observation about fixations made about twenty years led to a much deeper understanding of the causes and implications of the correlation between attention and microsaccades. Subsequent research also illuminates highly intriguing new questions about the integration of early visual processing capabilities in late motor control brainstem structures. These issues highlight the importance of approaching vision science from an active perspective incorporating the interplay between vision and eye movements.

Farran Briggs will describe a series of approaches using traditional and modern tools to explore how cortical feedback influences early visual processing. Transformations in visual signals traversing the feedforward retino-geniculo-cortical pathways are well understood, but the contribution of corticogeniculate feedback to visual perception is less clear. Through examinations of the morphology, physiology and function of corticogeniculate neurons, a new hypothesis emerges in which corticogeniculate feedback regulates the timing and precision of feedforward visual signal transmission.

Jude Mitchell will discuss how visual tasks have evolved over the past twenty years. Fixation paradigms have added much to our understanding but sidestep the dynamics of natural vision in which peripheral targets are selected (pre-saccadic attention) and brought to the fovea for detailed inspection (trans-saccadic integration). Jude will describe the application of free-viewing paradigms in the marmoset monkey to examine processing in visual cortex and the dynamics of selective attention across the saccade-to-fixation cycle.

Marlene Cohen will describe insights in understanding populations of neurons. Twenty years ago, most NHP work focused on the activity of single neurons and relatively simple stimuli and behaviors. It is now possible to record from many neurons in multiple brain areas while monkeys make judgments about a variety of stimulus properties. Marlene will describe recent work showing that these complex data sets can reveal strikingly simple relationships between neuronal populations and visual perception.

Nicole Rust will discuss how deep artificial neural networks (DANNs) have advanced our understanding of visual function. Work over the past twenty years has demonstrated striking parallels between DANNs trained to categorize objects and the functional organization of the primate ventral visual pathway. Nicole will describe work showing that DANNs serve not only as models for object identification, but also extend to other visual behaviors including ‘image memorability’ – why some images are better remembered than others.

Bevil Conway will discuss how functional MRI in NHPs has advanced our understanding of the ventral visual pathway. Combining fMRI with neurophysiology has facilitated the systematic study of extrastriate cortex, guided targeted recordings from neurons in functionally identified patches of cortex, and provided direct comparisons of brain activity in humans and monkeys. This work underscores the importance of understanding how functionally identified populations of neurons interact to enable perception of colors, objects, places and faces.

A vision for orienting in subcortical oculomotor control areas

Ziad Hafed[1]; [1]Eberhard Karls Universität Tübingen

Ziad Hafed will review how an observation about fixational eye movements, first described about 20 years ago, led to a series of studies exploring the brain circuits that control both attention and saccades. We now have a much deeper understanding of the underlying roots and implications of the correlation between attention and microsaccades, the role of subcortical and cortical visual structures in this process, and the importance of approaching vision from an active, rather than passive, perspective.

The role of corticogeniculate feedback in visual perception

Farran Briggs[1]; [1]University of Rochester

Farran Briggs will describe a series of approaches using traditional and modern tools to explore how cortical feedback influences early visual processing. Transformations in visual signals traversing the feedforward retino-geniculo-cortical pathways are well understood, but the contribution of corticogeniculate feedback to visual perception is less clear. Through examinations of the morphology, physiology and function of corticogeniculate neurons, a new hypothesis emerges in which corticogeniculate feedback regulates the timing and precision of feedforward visual signal transmission.

Neural circuits for pre-saccadic attention in the marmoset monkey

Jude Mitchell[1]; [1]University of Rochester

Jude Mitchell will describe the role of different classes of neurons in visual cortex. Over the past twenty years, there have been major advances towards manipulating and tagging different neuronal classes, and new molecular and recording techniques that distinguish cell class are now becoming available for use in NHPs. Jude will describe the application of these approaches in the marmoset monkey to understand how eye movements modulate early sensory processing as a function of cell class and cortical layer.

Multi-neuron approaches to studying visual perception and decision-making

Marlene Cohen[1]; [1]University of Pittsburgh

Marlene Cohen will describe insights in understanding populations of neurons. Twenty years ago, most NHP work focused on the activity of single neurons and relatively simple stimuli and behaviors. It is now possible to record from many neurons in multiple brain areas while monkeys make judgments about a variety of stimulus properties. Marlene will describe recent work showing that these complex data sets can reveal strikingly simple relationships between neuronal populations and visual perception.

Deep artificial neural networks as models of vision and visual memory

Nicole Rust[1]; [1]University of Pennsylvania

Nicole Rust will discuss the contributions of deep artificial neural networks (DANNs) to our understanding of visual cortical function. Work over the past twenty years has demonstrated striking parallels between DANNs trained to categorize objects and the functional organization of the primate ventral visual pathway. Nicole will describe recent work showing that DANNs serve not only as models for object identification, but also extend to other visual behaviors including ‘image memorability’, or the variation with which some images are better remembered than others.

Parallel multi-stage processing of inferior temporal cortex: faces, objects, colors and places

Bevil Conway[1]; [1]National Eye Institute

Bevil Conway will discuss how functional MRI in NHPs has advanced our understanding of the ventral visual pathway. Combining fMRI with neurophysiology has facilitated the systematic study of extrastriate cortex, guided targeted recordings from neurons in functionally identified patches of cortex, and provided a direct comparison of brain activity in humans and monkeys. This work underscores the importance of understanding how functionally identified populations of neurons interact to enable perception of colors, objects, places and faces.

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What has the past 20 years of neuroimaging taught us about human vision and where do we go from here?

Friday, May 21, 2:30 - 4:30 pm EDT, Talk Room 2 **Join Zoom Webinar**

Organizers: Susan Wardle[1], Chris Baker[1]; [1]National Institutes of Health
Speakers: Aina Puce, Frank Tong, Geoffrey K. Aguirre, Justin Gardner, and Marieke Mur

Over the past 20 years, neuroimaging methods have become increasingly popular for studying the neural mechanisms of vision in the human brain. To celebrate 20 years of VSS this symposium will focus on the contribution that brain imaging techniques have made to our field of vision science. In the year 2000, we knew about retinotopy and category-selectivity, but neuroimaging was still evolving. Now in 2020, the field is taking an increasingly computational approach to applying neuroimaging data to understanding questions about vision. The aim of this symposium is to provide both a historical context and a forward-focus for the role of neuroimaging in vision science. Our speakers are a diverse mix of pioneering researchers in the field who applied neuroimaging in the early days of the technique, and those who have more recently continued to push the field forward by creative application of imaging techniques. We have also selected speakers who use a range of different methodological approaches to investigate both low-level and high-level vision, including computational and modeling techniques, multivariate pattern analysis and representational similarity analysis, and methods that aim to link brain to behavior.

The session will begin with a short 5-10 min Introductory talk by Susan Wardle to provide context for the symposium. Talks by the five selected speakers will be 20 minutes each; with 1-2 mins available for clarification questions after each talk. The session will end with a longer 10-15 min general discussion period. In the first talk, Aina Puce will consider the contribution made by multiple neuroimaging techniques such as fMRI and M/EEG towards understanding the social neuroscience of face perception, and how technological advances are continuing to shape the field. In the second talk, Frank Tong will discuss progress made in understanding top-down feedback in the visual system using neuroimaging, predictive coding models, and deep learning networks. In the third talk, Janneke Jehee will argue that a crucial next step in visual neuroimaging is to connect cortical activity to behavior, using perceptual decision-making as an illustrative example. In the fourth talk, Justin Gardner will discuss progress made in using neuroimaging to link cortical activity to human visual perception, with a focus on quantitative linking models. In the final talk, Marieke Mur will reflect on what fMRI has taught us about high-level visual processes, and outline how understanding the temporal dynamics of object recognition will play an important role in the development of the next generation of computational models of human vision.

Overall, the combination of a historical perspective and an overview of current trends in neuroimaging presented in this symposium will lead to informed discussion about what future directions will prove most fruitful for answering fundamental questions in vision science.

Technological advances are the scaffold for propelling science forward in social neuroscience

Aina Puce[1]; [1]Indiana University

Over the last 20 years, neuroimaging techniques [e.g. EEG/MEG, fMRI] were used to map neural activity within a core and extended brain network to study how we use social information from faces. By the 20th century's end, neuroimaging methods had identified the building blocks of this network, but how these parts came together to make a whole was unknown. In 20 years, technological advances in data acquisition and analysis have occurred in a number of spheres. First, network neuroscience has progressed our understanding of which brain regions functionally connect with one another on a regular basis. Second, improvements in white matter tract tracing have allowed putative underlying white matter pathways to be identified for some functional networks. Third, [non-]invasive brain stimulation has allowed the identification of some causal relationships between brain activity and behavior. Fourth, technological developments in portable EEG and MEG systems propelled social neuroscience out of the laboratory and into the [ecologically valid] wide world. This is changing activation task design as well as data analysis. Potential advantages of these 'wild type' approaches include the increased signal-to-noise provided by a live interactive 3D visual stimulus e.g. another human being, instead of an isolated static face on a computer monitor. Fifth, work with machine learning algorithms has begun to differentiate brain/non-brain activity in these datasets. Finally, we are finally 'putting the brain back into the body' – whereby recordings of brain activity are made in conjunction with physiological signals including EKG, EMG, pupil dilation, and eye position.

Understanding the functional roles of top-down feedback in the visual system

Frank Tong[1]; [1]Vanderbilt University

Over the last 20 years, neuroimaging techniques have shed light on the modulatory nature of top-down feedback signals in the visual system. What is the functional role of top-down feedback and might there be multiple types of feedback that can be implemented through automatic and controlled processes? Studies of voluntary covert attention have demonstrated the flexible nature of attentional templates, which can be tuned to particular spatial locations, visual features or to the structure of more complex objects. Although top-down feedback is typically attributed to visual attention, there is growing evidence that multiple forms of feedback exist. Studies of visual imagery and working memory indicate the flexible nature of top-down feedback from frontal-parietal areas to early visual areas for maintaining and manipulating visual information about stimuli that are no longer in view. Theories of predictive coding propose that higher visual areas encode feedforward signals according to learned higher order patterns, and that any unexplained components are fed back as residual error signals to lower visual areas for further processing. These feedback error signals may serve to define an image region as more salient, figural, or stronger in apparent contrast. Here, I will discuss both theory and supporting evidence of multiple forms of top-down feedback, and consider how deep learning networks can be used to evaluate the utility of predictive coding models for understanding vision. I will go on to discuss what important questions remain to be addressed regarding the nature of feedback in the visual system.

Retinotopic mapping as a methodological engine of vision science fMRI

Geoffrey K. Aguirre[1]; [1]University of Pennsylvania

A fundamental property of the human visual system is the orderly representation of the retinotopic map across cortical visual areas. Thousands of people have undergone measurement of the cortical retinotopic map using fMRI, both for the purpose of studying the maps themselves, and as a prelude to the study of neural responses within the cortical visual areas. Investigators who obtain these data have worked steadily to improve every aspect of the collection, analysis, and interpretation of retinotopic maps. These methodological improvements have extended past the boundaries of map making, and now influence fMRI studies of all aspects of the visual system. Digital segmentation and unfolding of the cortical surface makes plain the regularity of cortical organization. The software tools that enable this feat became available to the scientific community twenty years ago, granting us all the ability to see what Gordon Holmes had to imagine. A new way of thinking about fMRI data was driven by the development of the population receptive field (pRF) technique. Instead of a focus upon the presence or absence of fMRI activity, we are invited instead to consider the parameters of a "forward model" that expresses neural response as a transformation of the stimulus. Finally, retinotopic mapping can now incorporate the influence of anatomical priors that underpin the organization of the cortical visual system at large and small scales. These and further advances in stimulus control, naturalistic stimuli, validation datasets, and eye tracking promise better maps, and exciting new vision science.

Using neuroimaging to link cortical activity to human visual perception

Justin Gardner[1]; [1]Stanford University

Over the last 20 years, human neuroimaging, in particular BOLD imaging, has become the dominant technique for determining visual field representations and measuring selectivity to various visual stimuli in the human cortex. Indeed, BOLD imaging has proven decisive in settling long standing disputes that other techniques such as electrophysiological recordings of single neurons provided only equivocal evidence for. For example, by showing that cognitive influences due to attention or perceptual state could be readily measured in so-called early sensory areas. Part of this success is due to the ability to make precise behavioral measurements through psychophysics in humans which can quantitatively measure such cognitive effects. Leveraging this ability to make quantitive behavioral measurements with concurrent measurement of cortical activity with BOLD imaging, we can provide answers to a central question of visual neuroscience: What is the link between cortical activity and perceptual behavior? To make continued progress in the next 20 years towards answering this question, we must turn to quantitative linking models that formalize hypothesized relationships between cortical activity and perceptual behavior. Such quantitative linking models are falsifiable hypotheses whose success or failure can be determined by their ability or inability to quantitatively account for behavioral and neuroimaging measurements. These linking models will allow us to determine the cortical mechanisms that underly visual perception and account for cognitive influences such as attention on perceptual behavior.

High-level vision: from category selectivity to representational geometry

Marieke Mur[1]; [1]Western University, London ON, Canada

Over the last two decades, functional magnetic resonance imaging (fMRI) has provided important insights into the organization and function of the human visual system. In this talk, I will reflect on what fMRI has taught us about high-level visual processes, with an emphasis on object recognition. The discovery of object-selective and category-selective regions in high-level visual cortex suggested that the visual system contains functional modules specialized for processing behaviourally relevant object categories. Subsequent studies, however, showed that distributed patterns of activity across high-level visual cortex also contain category information. These findings challenged the idea of category-selective modules, suggesting that these regions may instead be clusters in a continuous feature map. Consistent with this organizational framework, object representations in high-level visual cortex are at once categorical and continuous: the representational code emphasizes category divisions of longstanding evolutionary relevance while still distinguishing individual images. This body of work provides important insights on the nature of high-level visual representations, but it leaves open how these representations are dynamically computed from images. In recent years, deep neural networks have begun to provide a computationally explicit account of how the ventral visual stream may transform images into meaningful representations. I will close off with a discussion on how neuroimaging data can benefit the development of the next generation of computational models of human vision and how understanding the temporal dynamics of object recognition will play an important role in this endeavor.

< Symposia

Feedforward & Recurrent Streams in Visual Perception

Monday, May 24, 9:30 - 11:30 am EDT, Talk Room 1 Join Zoom Webinar

Organizers: Shaul Hochstein[1], Merav Ahissar[2]; [1]Life Sciences, Hebrew University, Jerusalem, [2]Psychology, Hebrew University, Jerusalem
Speakers: Jeremy M Wolfe, Shaul Hochstein, Catherine Tallon-Baudry, James DiCarlo, and Merav Ahissar

Forty years ago, Anne Treisman presented Feature Integration Theory (FIT; Treisman & Gelade, 1980). FIT proposed a parallel, preattentive first stage and a serial second stage controlled by visual selective attention, so that search tasks could be divided into those performed by the first stage, in parallel, and those requiring serial processing and further “binding” in an object file (Kahneman, Treisman, & Gibbs, 1992).

Ten years later, Jeremy Wolfe expanded FIT with Guided Search Theory (GST), suggesting that information from the first stage could guide selective attention in the second (Wolfe, Cave & Franzel, 1989; Wolfe, 1994). His lab’s recent visual search studies enhanced this theory (Wolfe, 2007), including studies of factors governing search (Wolfe & Horowitz, 2017), hybrid search (Wolfe, 2012; Nordfang, Wolfe, 2018), and scene comprehension capacity (Wick … Wolfe, 2019).

Another ten years later, Shaul Hochstein and Merav Ahissar proposed Reverse Hierarchy Theory (RHT; Hochstein, Ahissar, 2002), turning FIT on its head, suggesting that early conscious gist perception, like early generalized perceptual learning (Ahissar, Hochstein, 1997, 2004), reflects high cortical level representations. Later feedback, returning to lower levels, allows for conscious perception of scene details, already represented in earlier areas. Feedback also enables detail-specific learning. Follow up found that top-level gist perception primacy leads to the counter-intuitive results that faces pop out of heterogeneous object displays (Hershler, Hochstein, 2005), individuals with neglect syndrome are better at global tasks (Pavlovskaya … Hochstein, 2015), and gist perception includes ensemble statistics (Khayat, Hochstein, 2018, 2019; Hochstein et al., 2018). Ahissar’s lab mapped RHT dynamics to auditory systems (Ahissar, 2007; Ahissar etal., 2008) in both perception and successful/failed (from developmental disabilities) skill acquisition (Lieder … Ahissar, 2019)

James DiCarlo has been pivotal in confronting feedforward-only versus recurrency-integrating network models of extra-striate cortex, considering animal/human behavior (DiCarlo, Zoccolan, Rust, 2012; Yarmins … DiCarlo, 2014; Yamins, DiCarlo, 2016). His large-scale electrophysiology recordings from behaving primate ventral stream, presented with challenging object-recognition tasks, relate directly to whether recurrent connections are critical or superfluous (Kar … DiCarlo, 2019). He recently developed combined deep artificial neural network modeling, synthesized image presentation, and electrophysiological recording to control neural activity of specific neurons and circuits (Bashivan, Kar, DiCarlo, 2019).

Cathrine Tallon-Baudry uses MEG/EEG recordings to study neural correlates of conscious perception (Tallon-Baudry, 2012). She studied roles of human brain oscillatory activity in object representation and visual search tasks (Tallon-Baudry, 2009), analyzing effects of attention and awareness (Wyart, Tallon-Baudry, 2009). She has directly tested, with behavior and MEG recording, implications of hierarchy and reverse hierarchy theories, including global information processing being first and mandatory in conscious perception (Campana, Tallon-Baudry, 2013; Campana … Tallon-Baudry, 2016)

In summary, bottom-up versus top-down processing theories reflect on the essence of perception: the dichotomy of rapid vision-at-a-glance versus slower vision-with-scrutiny, roles of attention, hierarchy of visual representation levels, roles of feedback connections, sites and mechanisms of various visual phenomena, and sources of perceptual/cognitive deficits (Neglect, Dyslexia, ASD). Speakers at the proposed symposium will address these issues with both a historical and forward looking perspective.

Is Guided Search 6.0 compatible with Reverse Hierarchy Theory

Jeremy M Wolfe[1]; [1]Harvard Medical School and Visual Attention Lab Brigham & Women's Hospital

It has been 30 years since the first version of the Guided Search (GS) model of visual search was published. As new data about search accumulated, GS needed modification. The latest version is GS6. GS argues that visual processing is capacity-limited and that attention is needed to “bind” features together into recognizable objects. The core idea of GS is that the deployment of attention is not random but is “guided” from object to object. For example, in a search for your black shoe, search would be guided toward black items. Earlier versions of GS focused on top-down (user-driven) and bottom-up (salience) guidance by basic features like color. Subsequent research adds guidance by history of search (e.g. priming), value of the target, and, most importantly, scene structure and meaning. Your search for the shoe will be guided by your understanding of the scene, including some sophisticated information about scene structure and meaning that is available “preattentively”. In acknowledging the initial, preattentive availability of something more than simple features, GS6 moves closer to ideas that are central to the Reverse Hierarchy Theory of Hochstein and Ahissar. As is so often true in our field, this is another instance where the answer is not Theory A or Theory B, even when they seem diametrically opposed. The next theory tends to borrow and synthesize good ideas from both predecessors.

Gist perception precedes awareness of details in various tasks and populations

Shaul Hochstein[1]; [1]Life Sciences, Hebrew University, Jerusalem

Reverse Hierarchy Theory proposes several dramatic propositions regarding conscious visual perception. These include the suggestion that, while the visual system receives scene details and builds from them representations of the objects, layout, and structure of the scene, nevertheless, the first conscious percept is that of the gist of the scene – the result of implicit bottom-up processing. Only later does conscious perception attain scene details by return to lower cortical area representations. Recent studies at our lab analyzed phenomena whereby participants receive and perceive the gist of the scene before and without need for consciously knowing the details from which the gist is constructed. One striking conclusion is that “pop-out” is an early high-level effect, and is therefore not restricted to basic element features. Thus, faces pop-out from heterogeneous objects, and participants are unaware of rejected objects. Our recent studies of ensemble statistics perception find that computing set mean does not require knowledge of its individuals. This mathematically-improbable computation is both useful and natural for neural networks. I shall discuss just how and why set means are computed without need for explicit representation of individuals. Interestingly, our studies of neglect patients find that their deficit is in terms of tasks requiring focused attention to local details, and not for those requiring only global perception. Neglect patients are quite good at pop-out detection and include left-side elements in ensemble perception.

From global to local in conscious vison: behavior & MEG

Catherine Tallon-Baudry[1]; [1]CNRS Cognitive Neuroscience, Ecole Normale Supérieure, Paris

The reverse hierarchy theory makes strong predictions on conscious vision. Local details would be processed in early visual areas before being rapidly and automatically combined into global information in higher order area, where conscious percepts would initially emerge. The theory thus predicts that consciousness arises initially in higher order visual areas, independently from attention and task, and that additional and optional attentional processes operating from top to bottom are needed to retrieve local details. We designed novel textured stimuli that, as opposed to Navon's letters, are truly hierarchical. Taking advantage of both behavioral measures and of the decoding of MEG data, we show that global information is consciously perceived faster than local details, and that global information is computed regardless of task demands during early visual processing. These results support the idea that global dominance in conscious percepts originates in the hierarchical organization of the visual system. Implications for the nature of conscious visual experience and its underlying neural mechanisms will be discussed.

Next-generation models of recurrent computations in the ventral visual stream

James DiCarlo[1]; [1]Neuroscience, McGovern Inst. & Brain & Cognitive Sci., MIT

Understanding mechanisms underlying visual intelligence requires combined efforts of brain and cognitive scientists, and forward engineering emulating intelligent behavior (“AI engineering”). This “reverse-engineering” approach has produced more accurate models of vision. Specifically, a family of deep artificial neural-network (ANN) architectures arose from biology’s neural network for object vision — the ventral visual stream. Engineering advances applied to this

ANN family produced specific ANNs whose internal in silico “neurons” are surprisingly accurate models of individual ventral stream neurons, that now underlie artificial vision technologies. We and others have recently demonstrated a new use for these models in brain science — their ability to design patterns of light energy images on the retina that control neuronal activity deep in the brain. The reverse engineering iteration loop — respectable ANN models to new ventral stream data to even better ANN models — is accelerating. My talk will discuss this loop: experimental benchmarks for in silico ventral streams, key deviations from the biological ventral stream revealed by those benchmarks, and newer in silico ventral streams that partly close those differences. Recent experimental benchmarks argue that automatically-evoked recurrent processing is critically important to even the first 300msec of visual processing, implying that conceptually simpler, feedforward only, ANN models are no longer tenable as accurate in silico ventral streams. Our broader aim is to nurture and incentivize next generation models of the ventral stream via a community software platform termed “Brain-Score” with the goal of producing progress that individual research groups may be unable to achieve.

Visual and non-visual skill acquisition – success and failure

Merav Ahissar[1]; [1]Psychology Department, Social Sciences & ELSC, Hebrew University, Israel

Acquiring expert skills requires years of experience – whether these skills are visual (e.g. face identification), motor (playing tennis) or cognitive (mastering chess). In 1977, Shiffrin & Schneider proposed an influential stimulus-driven, bottom-up theory of expertise automaticity, involving mapping stimuli to their consistent response. Integrating many studies since, I propose a general, top-down theory of skill acquisition. Novice performance is based on the high-level multiple-demand (Duncan, 2010) fronto-parietal system, and with practice, specific experiences are gradually represented in lower-level domain-specific temporal regions. This gradual process of learning-induced reverse-hierarchies is enabled by detection and integration of task-relevant regularities. Top-down driven learning allows formation of task-relevant mapping and representations. These in turn form a space which affords task-consistent interpolations (e.g. letters in a manner crucial for letter identification rather than visual similarity). These dynamics characterize successful skills. Some populations, however, have reduced sensitivity to task-related regularities, hindering their related skill acquisition, preventing specific expertise acquisition even after massive training. I propose that skill-acquisition failure, perceptual as cognitive, reflects specific difficulties in detecting and integrating task-relevant regularities, impeding formation of temporal-area expertise. Such is the case for individuals with dyslexia (reduced retention of temporal regularities; Jaff-Dax et al., 2017), who fail to form an expert visual word-form area, and for individuals with autism (who integrate regularities too slowly for online updating; Lieder et al., 2019). Based on this general conceptualization, I further propose that this systematic impediment.

< Symposia

What's new in visual development?

Monday, May 24, 9:30 - 11:30 am EDT, Talk Room 2 Join Zoom Webinar

Organizers: Oliver Braddick[1], Janette Atkinson[2]; [1]University of Oxford, [2]University College London
Speakers: Oliver Braddick, Heather L. Kosakowski, T. Rowan Candy, Janette Atkinson, Tessa Dekker, and Dennis M Levi

In the last two decades, the science of human development has moved beyond defining how and when basic visual functions emerge during infancy and childhood, through both technical and conceptual advances. First, technical progress in MRI and near infrared spectroscopy and dedicated efforts by researchers have made it possible to image and localize activity in the visual brain, as early as the first months of life. These will be exemplified in the symposium by Heather Kosakowski presentation on the development of area specialization within the ventral visual stream in early infancy, and in Tessa Dekker's research on childhood development of decision making for efficient visual cue combination, combining neuroimaging with novel behavioural measures. Secondly, Rowan Candy's presentation will show how measurements of infants' eye movements and refractive state using Purkinje image eye tracking and photorefraction have been refined to new levels of accuracy, providing novel insights into oculomotor development and how it interacts with binocular visual experience from the first weeks of life. This work offers the possibility of understanding the early development of strabismus where accommodation-vergence synergy develops atypically. The resulting condition of amblyopia reflects early plasticity, but the work presented by Dennis Levi shows that this condition remains treatable into adulthood, using novel therapies designed to re-establish binocular interactions rather than simply strengthen the cortical input from the amblyopic eye, with new implications for extended critical periods.

Third, these approaches, alongside new behavioural methods , have highlighted the interlocking relationships between basic visual functions and visuocognitive processes such as decision-making and attention. Janette Atkinson's presentation will define the key role of attention in visual development, and how different components of attention, depending on distinct brain networks, can be separated in young children and those with neurodevelopmental disorders. Different disorders (e.g. perinatal brain damage, Down and Williams syndromes) show distinctive profiles of attentional impairment. Imaging studies of cortical area and fibre tract development suggest that specific parietal and frontal networks are associated with individual differences in children's visual decision-making and may also develop atypically across many developmental disorders. Tessa Dekker's presentation will show how decision processes operating on visual information are as critical in development, including visuomotor development, as the development of basic sensitivity to visual feature properties. Detailed modelling of visual and visuomotor behaviour and localised brain responses indicate a prolonged development into middle & late childhood of the integrative processes required for efficient visual decisions.

These talks illustrate some highlights in a much wider field of new insights into both typical and atypical visual development. Oliver Braddick's presentation will outline the scope of this broader field, including pointers to work on automated visual assessment, infant eye-tracking with head-mounted cameras in the natural visual environment, isolating specific discriminations through frequency-tagging EEG, MRI analyses of developing brain connectivity, and the developmental impact of early and late visual deprivation. This whole range of work has greatly extended our understanding of the developing visual brain and its intimate links throughout neurocognitive systems, and allows us to identifiy the challenges ahead.

New techniques, new questions in visual development

Oliver Braddick[1]; [1]University of Oxford

In the last two decades, the range of research on visual development has been expanded by new methodologies, some represented in this symposium, which provide richer data and more direct insights into the visual brain mechanisms underlying development. This talk provides a brief overview of other advances which have started to answer some key questions in visual development: (i) application of eye tracking to automated visual assessment; (ii) head-mounted eye tracking yielding data on how infants sample their natural visual environment; (iii) frequency-tagging to refine the specificity of information yielded by EEG; (iv) MRI approaches to the connectivity and structure of the developing visual brain, including individual differences in development; (v) broader studies of the impact of visual deprivation on human visual development. As well as applying new methods, developmental research, in common with vision research more generally, has also extended its scope into the interfaces of vision with attention, action systems, decision processes, and other aspects of cognition. All these advances open the prospects of a wider and deeper understanding of the role of vision in the development of brain systems in infancy and childhood. However, there remain challenges in understanding the origins of individual differences across children in visuospatial, visuomotor, and visuosocial cognition.

Object Responses in the Ventral and Dorsal Pathway of Human Infants

Heather L. Kosakowski[1], Michael Cohen[1,2], Nancy Kanwisher[1], Rebecca Saxe[1]; [1]Massachussetts Institute of Technology, [2]Amherst College

Recently we reported fMRI studies in infants showing selectivity for faces, scenes, and bodies in the ventral visual pathway (Kosakowski et al., VSS 2020). But in adults, visual stimuli also elicit strong responses in the dorsal pathway, in parietal regions that have long been implicated in visually guided action, and more recently in intuitive inferences about the physical world (Fischer et al., 2016). Further, behavioral evidence indicates infants understand the basic physical properties of objects from birth and continue to build an intuitive physical understanding throughout infancy (Baillergeon, 1998). Thus, we tested the hypotheses that regions of the dorsal pathway in infants might show a) strong responses to objects and b) functional response profiles resembling those in regions implicated in intuitive physical inference in adults (namely, objects>bodies>scenes>faces). With fMRI data from awake infants (2-9 months, n=30), we successfully identified regions responding to objects (more than the average of faces, scenes, and bodies) in both ventral and dorsal pathways. We further characterized the response of these regions in held out data. In the ventral pathway, the “object” voxels responded to inanimate, relative to animate conditions (objects≈scenes>faces≈bodies). Conversely, the regions in the dorsal pathway, particularly in the parietal cortex, showed a distinct profile (objects>bodies>>faces>scenes), similar to responses in the adult dorsal pathway. Thus, beyond the category-selective responses to faces, bodies, and scenes in the ventral visual pathway, infants also show robust responses to objects, including activations in the dorsal pathway that resemble the responses implicated in intuitive physical inference in adults.

Infants’ control of their visual experience through vergence and accommodation

T. Rowan Candy[1]; [1]University of Indiana

While a large literature has demonstrated the impact of abnormal visual experience on postnatal development of the visual system, the role of the ocular motor visual system in defining retinal visual experience during infancy and early childhood has been less well understood. Advances in instrumentation have made it possible for us to track simultaneously infants’ vergence eye movements and accommodation, showing that these responses are coupled, associated with sensitivity to binocular disparity, and can be dynamically adjusted, from the first weeks of life. This control, along with that of conjugate eye movements, enables infants to control their own visual experience in their dynamic three-dimensional world. In turn, visual experience enables most children to calibrate these coupled responses effectively, while others develop misalignment of their eyes and strabismus. A key question for future studies is to explore the source of this individual failure, whether it lies in disrupted fusional vergence potential or in the ability to undergo adaptation. This talk will also briefly consider the following questions: How does the improving spatial resolution of the infant’s visual system affect the iterative development of motor and sensory visual systems? How can human visual development inform machine learning and robotics? How does development of the first stages of visual processing impact higher-order extrastriate function, and what is the influence of top-down processes?

Typical and atypical brain development for components of visual attention

Janette Atkinson[1]; [1]University College London

Developing attention mechanisms play a key role in how visual information is used, and determine how the visual environment shapes visual development. However, visual attention is not a unitary process but involves multiple components of selective attention, sustained attention, and executive function(s). The Early Childhood Attention Battery (ECAB) separately measures these components in preschool children (or equivalent mental age), defining individual ‘attention profiles’ and group differences across these components. For example, we find that sustained visual attention is impaired in children with perinatal brain injury but is relatively preserved in children with Williams (WS). Children with Down Syndrome or WS have difficulties inhibiting prepotent responses in executive function tasks, although in WS these difficulties are much greater in the visuospatial than the verbal domain. In new data using the ECAB in a dietary supplementation trial to reduce the impact of perinatal brain injury, we find that executive function is specifically improved in the treated group. Our work has highlighted attention deficits as part of the ‘dorsal stream vulnerability’ characterising many developmental disorders. We discuss these patterns of deficit across syndromes in relation to the dorsal and ventral attention networks and salience network defined in current connectivity studies in children and adults, including our findings on the tracts associated with children’s performance on visual decisions. Individual variations in how these networks interact may determine how top-down goals and bottom-up sensory stimulation are integrated in the control of visual behaviour in development.

Model-based MRI and psychophysics reveal crucial role of decision-making in visual development in childhood.

Tessa Dekker[1], Marko Nardini[2], Peter Jones[1]; [1]University College London, [2]University of Durham

Vision undergoes major development during infancy and childhood, demonstrated in improvements in both detection and recognition tasks. Classically, developmental vision research has focussed on sensitivity improvements in early visual channels. However, in recent years, decision-theoretic approaches have formalised how changes in visual performance could also result from more efficient use of available information, for example by optimising decision rules, cost functions, and priors. Using these quantitative frameworks, we are beginning to understand how these factors contribute to childhood vision. For example, improved depth perception in late childhood reflects a shift from processing depth cues independently to combining them in visual cortex, as demonstrated by the emergence of fMRI evidence for fused depth-cue representations within neural detectors in area V3B. Similarly, development of visual motion-, location-, and object perception, in part reflects more efficient combining of stimulus features (e.g., averaging dots across displays) besides greater sensitivity to these features’ properties (e.g., single dot motion). Thus, rather than greater sensitivity to basic visual information, substantial improvements in visual discrimination and detection may reflect better inferential capacities. This also applies to visually-guided movement tasks that emulate real-life action under risk: while adults can rapidly identify visuomotor strategies that minimise risk and uncertainty in new situations with complex cost factors, children up to age 10 years do not. Together, these studies show that improved decision-making plays a major role in visual development in childhood, and that modelling this role is needed to gain computational-level insight in the driving factors of human visual plasticity.

Rethinking amblyopia and its therapies

Dennis M Levi[1]; [1]University of California Berkeley

Recent work has transformed our ideas about effective therapies for amblyopia. Since the 1700’s, the clinical treatment for amblyopia has consisted of patching or penalizing the strong eye, to force the “lazy” amblyopic eye, to work. This treatment has generally been limited to infants and young children during the “critical” or sensitive period of development. Over the last 20 years, we have learned much about the nature and neural mechanisms underlying the loss of spatial and binocular vision in amblyopia, and that a degree of neural plasticity persists well beyond the sensitive period. Importantly, the last decade has seen a resurgence of research into new approaches to the treatment of amblyopia both in children and adults, which emphasise that monocular therapies may not be the most effective for the fundamentally binocular disorder that is amblyopia. These approaches include perceptual learning, video game play and binocular methods aimed at reducing inhibition of the amblyopic eye by the strong fellow eye, and enhancing binocular fusion and stereopsis. This talk will highlight both the successes of these approaches in labs around the world, and their dismal failures in clinical trials. Reconciling these results raises important new questions that may help to focus future directions.

< Symposia

Talk Sessions Overview

Friday, May 21

Talk Room 1

Visual Search

Friday, May 21, 10:30 - 11:45 am EDT, Talk Room 1 Join Zoom Webinar

Attention: Models and mechanisms

Friday, May 21, 12:30 - 2:00 pm EDT, Talk Room 1 Join Zoom Webinar

Talk Room 2

Plasticity and Learning

Friday, May 21, 10:30 am - 12:00 pm EDT, Talk Room 2 Join Zoom Webinar

3D Perception and Stereopsis

Friday, May 21, 12:30 - 2:00 pm EDT, Talk Room 2 Join Zoom Webinar

Saturday, May 22

Talk Room 1

Attention: Features, objects, salience

Saturday, May 22, 10:30 am - 12:00 pm EDT, Talk Room 1 Join Zoom Webinar

Spatial Vision

Saturday, May 22, 2:30 - 4:00 pm EDT, Talk Room 1 Join Zoom Webinar

Attention, Search, Memory, Crowding

Saturday, May 22, 8:00 - 10:00 pm EDT, Talk Room 1 Join Zoom Webinar

Talk Room 2

Face Perception: Models and mechanisms

Saturday, May 22, 10:30 am - 12:00 pm EDT, Talk Room 2 Join Zoom Webinar

Development

Saturday, May 22, 2:30 - 4:00 pm EDT, Talk Room 2 Join Zoom Webinar

Sunday, May 23

Talk Room 1

Visual Memory: Working and long-term

Sunday, May 23, 10:30 am - 12:00 pm EDT, Talk Room 1 Join Zoom Webinar

Motion Perception

Sunday, May 23, 12:30 - 2:00 pm EDT, Talk Room 1 Join Zoom Webinar

Talk Room 2

Perception and Action

Sunday, May 23, 10:30 am - 12:00 pm EDT, Talk Room 2 Join Zoom Webinar

Eye movements: Saccades, pursuit, vergence

Sunday, May 23, 12:30 - 2:00 pm EDT, Talk Room 2 Join Zoom Webinar

Monday, May 24

Talk Room 1

Color, Texture and Material

Monday, May 24, 12:00 - 1:30 pm EDT, Talk Room 1 Join Zoom Webinar

Talk Room 2

Scene Perception

Monday, May 24, 12:00 - 1:30 pm EDT, Talk Room 2 Join Zoom Webinar

Tuesday, May 25

Talk Room 1

Perceptual Organization

Tuesday, May 25, 10:30 am - 12:00 pm EDT, Talk Room 1 Join Zoom Webinar

Multisensory Processing

Tuesday, May 25, 1:00 - 2:30 pm EDT, Talk Room 1 Join Zoom Webinar

Face Perception

Tuesday, May 25, 8:00 - 10:00 pm EDT, Talk Room 1 Join Zoom Webinar

Talk Room 2

Eye Movements: Extra-retinal processes, scanpaths

Tuesday, May 25, 10:30 am - 12:00 pm EDT, Talk Room 2 Join Zoom Webinar

Visual Memory: Capacity, models, neural and encoding

Tuesday, May 25, 1:00 - 2:30 pm EDT, Talk Room 2 Join Zoom Webinar

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Wednesday, May 26

Talk Room 1

Objects and Scenes: Models and mechanisms

Wednesday, May 26, 10:30 am - 12:00 pm EDT, Talk Room 1 Join Zoom Webinar

Cortical Hierarchy and Computation

Wednesday, May 26, 1:00 - 2:30 pm EDT, Talk Room 1 Join Zoom Webinar

Talk Room 2

Decision Making

Wednesday, May 26, 10:30 am - 12:00 pm EDT, Talk Room 2 Join Zoom Webinar

Face Perception: Psychophysics

Wednesday, May 26, 1:00 - 2:30 pm EDT, Talk Room 2 Join Zoom Webinar

Visual Search

Friday, May 21, 10:30 - 11:45 am EDT, Talk Room 1 Join Zoom Webinar

Moderator: Alejandro Lleras, University of Illinois

10:30 am

Semantic content allows flexible memory-partitioning in hybrid search

Nurit Gronau[1] nuritgro@openu.ac.il, Makaela Nartker[2], Sharon Yakim[1,3], Igor Utochkin[4], Jeremy Wolfe[5,6]; [1]The Open University of Israel, [2]Johns Hopkins University, [3]The Hebrew University of Israel, [4]HSE University, Russia, [5]Brigham and Women's Hospital, [6]Harvard Medical School

In 'hybrid search,' people look for one of several memorized targets among irrelevant distractors. Sometimes, only a subset of these targets is relevant to current task demands. Can we flexibly partition our memory into different target subsets and search only for relevant targets? Boettcher et al. (2017) found that participants fail to partition memory into two arbitrary subsets on a trial-by-trial basis: reaction times resembled search for the full target set. These findings were replicated even when using natural categories, perhaps because the categories suffered from large semantic overlap. Here, we tested more semantically distinct object categories. In Experiment 1, the target subsets were additionally dissociated from each other by colored overlays. Results confirmed that extrinsic characteristics like color were not effective for memory partitioning, but participants could limit search to the relevant category (e.g., search only for animals, in blocks containing animal and vehicle targets). However, searching through categorical subsets of 8 out of 16 items was still slower than searching with only 8 items in memory. In Experiment 2, spatial location was used as a retrieval cue to boost memory partition. For example, animal targets might be learned and searched for on the right, vehicles on the left. Partition was fully effective: search for the 8 relevant targets on a trial was the same as search with just 8 items in memory. In Experiments 1 and 2, the distractors could cue the relevant memory subset on each trial. Experiment 3 eliminated that cue, and included task-irrelevant 'lures' from the other category in memory. Results still showed successful partition on the basis of semantic category. Thus, people can effectively switch between a memory set used while searching for cookies and chips in the snack aisle, and a set of vegetables that they would search for in the produce aisle.

Acknowledgements: This research was funded by ISF 1622/15 (to NG) and NEI EY017001 (to JW)

10:45 am

Attention guidance by learned spatial regularities associated with object categories

Ziyao Zhang[1] ziz418@lehigh.edu, Nancy Carlisle[1]; [1]Lehigh University

Regularities in the environment effectively guide attention. Our previous work has shown that participants quickly learned multiple spatial distributions associated with specific search targets. Importantly, on a trial-by-trial basis these target-specific spatial distributions were activated to bias attention toward likely target locations. This work implies implicit statistical learning is constrained by top-down goals. Within this novel finding, it remains unclear what information underlies these object-location associations. Is it an individual stimulus or the stimulus category that is linked to the spatial distributions? In four experiments, we probed the representations of learned associations with visual and categorical cues. In the learning phase, participants learned spatial distributions of 16 exemplars from four categories through cued visual search tasks. Exemplars from the same category shared a spatial distribution including a high (80%) and low (20%) probability location. In the testing phase, targets appeared at either location with equal likelihood to ensure the results were driven by prior learning. We ensured the spatial biases remained for learned exemplars (LE), while also testing whether the learning transferred to novel exemplars from learned categories (LC). In Experiment 1-3, participants received only visual cues in the learning block, we found the learning from LEs transferred to LCs when participants received a visual cue. However, no evidence of learning or transfer was found when participants received verbal categorical cues in the testing phase. In Experiment 4, participants were trained with categorical cues in the learning block. In the testing block, these categorical cues triggered spatial biases. However, neither visual cues of LEs

nor LCs triggered learned biases. This suggests that activation of the associations is strictly constrained by the cued information. Together, our results confirmed that people can acquire object-location associations through search experience, and demonstrated that stimulus categories drove the activation of spatial biases.

11:00 am

Evidence for parallel processing of relational information in visual search

Rachel Heaton[1] rmflood2@illinois.edu, Simona Buetti[1], Alejandro Lleras[1], John Hummel[1]; [1]University of Illinois

Visual search tasks with relation-based stimuli are more difficult for subjects than feature-based searches. Because the response time (RT) curves as a function of set size for target-present conditions have heretofore appeared to be linear in relational searches, it has been argued that subjects use a fully serial process during a search for a relational target (Logan, 1994). In three experiments, we show that search RT for relational stimuli follows a logarithmic function of set size, rather than a linear function, when a wider range of set sizes are included as conditions, which suggests that some parallel processing is present even during putatively relation-only searches. Using relation-only, difficult feature-only, and feature+relation search conditions, we showed that difficult feature-only search RTs follow a logarithmic curve, as expected, but that a relation-only search also follows a logarithmic curve, albeit steeper. When the relation must be used to find the search target, the feature+relation condition is more efficient than the feature-only condition, indicating the relation information is helping with parallel processing. We also show that when search stimuli are designed such that search can be reduced to a feature (color) only search, both feature-only and feature+relation conditions are more efficient, suggesting that the presence of relational information does not affect search slopes when the relations are irrelevant to the search, even if such information could be diagnostic. Finally, we found that spacing out search items increases the efficiency of relation-only search, meaning that nearby inter-item interactions that could produce texture fields or perceptual grouping cues are unlikely to be the cause of apparent parallel processing of relations, and in fact may inhibit parallel processing of relations.

Acknowledgements: This material is based upon work supported by the National Science Foundation under Grant No BCS1921735 to SB

11:15 am

Implementing TVA as a Bayesian classifier in a foraging task

Sofia Tkhan Tin Le[1] l.t.t.sophie@gmail.com, W.Joseph MacInnes[1], Árni Kristjánsson[1]; [1]HSE University

Foraging involves a natural search for many targets. Kristjánsson and colleagues (2014) found that changes in human foraging strategies depend on the complexity of the target and distractor relations. We aimed to understand the mechanisms underlying these differences. Bundesen’s (1990) TVA model involves an attempt at explicating the attentional mechanisms needed for selection, dividing the selection process into filtering and pigeonholing of the sensory input from the visual system and parameters from the executive system. We will combine these ideas in a generative model to simulate human foraging during a computerized task. First, we created a series of classifiers to determine which scene properties were important for predicting human behavior. Data from Kristjánsson et al. (2014) was used as input for a Naïve Bayesian model and an augmented Naïve Bayesian classifier. Switching rates between target types were the initial predictive parameter. EM log-likelihood and the strength of influence between parameters revealed high accuracy for both the Naïve Bayesian network and the augmented Naïve Bayesian network for conjunction foraging, and both models showed a connection between switching and previously selected target. We also looked at the strength of learned connections with network variables to see if they matched cognitive aspects of search behavior, and confirmed that switching appears regardless of the type of target stimulus. There was also a strong connection between switching and target type. This result relates to previous foraging findings in humans, which indicate that changes in search strategies depend on the complexity of objects in the visual field. The obtained Bayesian networks confirmed the general finding that increasing the complexity of the target changes foraging behavior minimizing switches in favor of exhaustive foraging of one category.

11:30 am

Sequentially dependent errors generalize across naturalistic mammogram stimuli

Cristina Ghirardo[1], Zhihang Ren[1], Zixuan Wang[1], Mauro Manassi[1,2], Min Zhou[3], David Whitney[1]; [1]University of California, Berkeley, [2]University of Aberdeen, Kings College, Aberdeen, UK, [3]The First People's Hospital of Shuangliu District, Chengdu

Radiologists rely on visual search to locate and identify lesions in mammograms. An underlying assumption in radiology is that the perception of each mammogram is free from the influence of preceding images; however, that may not be the case. Serial dependence, the tendency for the visual system to represent images as more similar to those previously viewed, occurs most frequently between ambiguous stimuli just like those found in radiological screening. (Cicchini, et al., PNAS, 2014; Fischer & Whitney, Nature Neuro, 2014; Liberman et al., Curr Bio, 2014; Kiyonaga et al., TiCS, 2017). Recent work has shown radiologists' perception of simulated tumors is biased toward previously seen stimuli (Manassi et al., Sci Reports, 2019; Ghirardo et. al., VSS, 2020). This serial dependence could cause diagnostic errors; however, previous work on this hypothesis was limited to artificial, unrealistic stimuli. To overcome these limitations, we used a generative adversarial network to create naturalistic simulated mammogram images via interpolation (Ren et al., VSS, 2020), which radiologists misclassified as real mammograms. From these, we created sets of similar simulated mammograms. Using these as stimuli in a standard serial dependence experiment, untrained observers viewed a random simulated mammogram on each trial and subsequently matched the mammogram using continuous report. We found serial dependence with all of the simulated radiographs: the reported mammograms were pulled ~9-12% toward those previously seen. The effect extended back at least two trials (~10 sec). These findings suggest that serial dependence extends to realistic radiographs, and that it may contribute to some of the misdiagnoses found in radiological practice.

Acknowledgements: National Institutes of Health grant 5R01CA236793-02

Plasticity and Learning

Friday, May 21, 10:30 am - 12:00 pm EDT, Talk Room 2 Join Zoom Webinar

Moderator: Peter Bex, Northeastern University

10:30 am

Theta power and theta-gamma coupling during formation of novel representations in the infant brain

Emma Ward[1] emma.ward@fu-berlin.de, Ezgi Kayhan[2], Christian Kliesch[3], Radoslaw Cichy[1], Stefanie Hoehl[4], Moritz Köster[1]; [1]Freie Universitaet Berlin, [2]University of Potsdam, [3]Mainz University, [4]University of Vienna

Building object representations is crucial for understanding the visual world, but it is not yet understood how infants start to form these representations. In adults, theta power is higher during presentation of stimuli that were later remembered, compared to those later forgotten (Friese et al., 2013), and the coupling between theta phase and gamma amplitude has been shown to be responsible for binding perceptual features to form representations. Theta-gamma coupling has been observed, for example, during the formation of visual associations (Köster, Finger, Graetz, Kater & Gruber, 2018), and was again higher for remembered than forgotten stimuli. Theta-gamma coupling has not yet been examined in infants due to methodological difficulties, such as contamination of the EEG signal by microsaccades (Köster, 2016) and low signal-to-noise ratio (Hoehl & Wahl, 2012). Since infants are in the process of building novel representations of their environment all the time, they are well-suited to show how early representations can begin to form. The current study introduces tools to solve these limitations and examines the neuronal processes related to forming new representations in 48 infants (6;12 – 8;04 months old). At the beginning of the experiment, infants were familiarised with four stimuli. They then saw interleaved trials showing either a familiar object or an entirely novel object. EEG was recorded continuously and wavelet transformed to time-frequency space. We expected that infants would show higher theta power for novel compared to familiar stimuli, and that theta-gamma coupling would be higher for novel compared to familiar stimuli. Our results show increased parietal and frontal theta for novel compared to familiar objects, in line with theta's role in building semantic conceptual networks. We were successful in removing microsaccade artifacts from the infant EEG and will further present the data on the cross-frequency coupling between theta phase and gamma amplitude.

10:45 am

A demonstration of cone function plasticity after gene therapy in achromatopsia

Mahtab Farahbakhsh[1] m.farahbakhsh.16@ucl.ac.uk, Elaine J. Anderson[1], Andy Rider[1], John A. Greenwood[1], Nashila Hirji[1,4], Serena Zaman[1,4], Pete R. Jones[1,2], D. Samuel Schwarzkopf[1,3], Geraint Rees[1], Michel Michaelides[1,4], Tessa M. Dekker[1]; [1]University College London, London, UK, [2]City University, London, UK, [3]University of Auckland, NZ, [4]Moorfields Eye Hospital, London, UK

Achromatopsia (ACHM) is an inherited retinal disease characterised by complete loss of cone photoreceptor function from birth. In recent years, gene therapies have successfully been used to induce signal processing in dormant cones in animal models of ACHM, with greater functional benefits for younger animals. With several completed or on-going clinical trials of gene therapy for ACHM, preliminary evidence suggests that effects on visual function in adults with ACHM may be subtle. Given the known constraints of age on neural plasticity, it is possible that gene therapy earlier in life will have a greater impact. Sensitive, child-friendly tests of cone function are therefore needed to facilitate the optimisation of these treatment strategies. Here, we present a new method that leverages a multimodal approach, linking psychophysical estimates of cone function to cone-mediated signals in visual cortex, measured using fMRI population receptive field (pRF) mapping. To selectively stimulate rod and cone photoreceptors, we used silent substitution. In a case study of two children with ACHM undergoing gene therapy, we find individual differences in recovery of cone function over time. Before treatment, measures from both patients resembled those of 10 other untreated ACHM patients. After gene therapy, one patient demonstrated strong concurrent evidence of improved cone

function, and retinotopically organised responses in visual cortex (V1-3) to cone-selective stimuli, with measures closely resembling those of 26 age-matched controls. Head motion, fixation stability, and task performance were very similar before and after treatment, so it is highly unlikely that these results are driven by measurement confounds. We conclude that our multimodal approach is feasible for use in children with low vision. Our fMRI and psychophysical measures show significant potential not only for sensitive evaluation of new sight-rescuing therapies, but also for revealing the neural mechanisms based on which these treatments operate in the developing brain.

Acknowledgements: NIHR BRC at Moorfields Eye Hospital (MEH) and UCL Institute of Ophthalmology, ESRC, MeiraGTx, Retina UK, MEH Special Trustees, Moorfields Eye Charity, Foundation Fighting Blindness, Wellcome Trust, Ardalan Family Scholarship, Maryam Mirzakhani Scholarship, Sir Richard Stapley Educational Trust.

11:00 am

Amblyopia-Related Changes in the Fine-Scale Functional Organization of Human Extrastriate Visual Cortex

Bryan Kennedy[1] bkennedy7@mgh.harvard.edu, Amanda Nabasaliza[1,4], Peter Bex[3], David G. Hunter[4,5], Roger B.H. Tootell[1,2], Shahin Nasr[1,2]; [1]Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Boston, MA, [2]Department of Radiology, Harvard Medical School, Boston, MA, [3]Department of Psychology, Northeastern University, Boston, MA, [4]Department of Ophthalmology, Boston Children’s Hospital, Boston, MA, [5]Department of Ophthalmology, Harvard Medical School, Boston, MA

Background: Amblyopia is a developmental disorder caused by disruption of symmetric binocular visual input early in life. Most amblyopic individuals suffer from impaired stereopsis. Experimental models of amblyopia in non-human primates suggest a significant reduction in the number of stereo-selective neurons within the extrastriate visual cortex. However, these studies were based on a monocular deprivation model that differs from the asymmetric binocular vision of human amblyopes. Here, we studied the impact of strabismus and anisometropia (two major natural causes of amblyopia) on the functional organization of fine-scale neuronal structures (including the stereo-selective stripes/columns) in human extrastriate visual cortex. Methods: We tested the functional organization of color-selective thin- and stereo/motion-selective thick-type stripes/columns in areas V2/V3 in 5 amblyopic (3 strabismic and 2 anisometropic) and 14 control individuals. We used high-resolution (1 mm isotropic) fMRI (7T), to localize these fine-scale structures based on their response to color-vs-luminance varying stimuli (Nasr et al., 2016), 3D-vs-2D random dot stereograms (Nasr and Tootell, 2018) and moving-vs-stationary stimuli (Tootell and Nasr, 2020). Results: Controls (≈50 arc sec randot stereoacuity) showed stereo-selective stripes/columns in V2/V3. In contrast, amblyopic individuals (>250 arc sec) showed no significant ($p>0.05$) stereo-selective activity in V2/V3 (see also Nasr et al., abstract). Nevertheless, interdigitated clusters of motion- and color-selective responses were still found in areas V2/V3 of amblyopic individuals, as detected in controls. Interestingly, the surface area occupied by the motion- and color-selective stripes/clusters was significantly larger ($p<0.05$) in amblyopic compared to control individuals. We did not find any significant difference in the number of non-selective and/or non-responsive vertices between the two groups, ruling out a general sensitivity loss hypothesis. Conclusion: The absence of proper binocular input in amblyopia leads to a decrease in the size of stereo-selective stripes/columns, with a corresponding increase in the size of motion- and color-selective sites.

Acknowledgements: This work was supported by NIH NEI (grants R01EY026881 and R01EY030434), and by the MGH/HST Athinoula A. Martinos Center for Biomedical Imaging. Crucial resources were made available by a NIH Shared Instrumentation Grant S10-RR019371.

11:15 am

Physics 101: The visual systems ability to learn and integrate Newtonian predictions

Abdul Deeb[1] abdul-rahim_deeb@brown.edu, Fulvio Domini[1]; [1]Brown University

The motions of objects in the environment reflect underlying dynamical constraints and regularities. Shepard (1984) first proposed that the perceptual system may have internalized these regularities to constrain how the system handles missing visual information. A recent body of work has demonstrated that not only is vision constrained by physical laws, but that these regularities can directly modulate motion perception when displayed events are inconsistent with events in the physical world (Deeb, Cesanek, Domini, 2021). In this current study we show that the visual system is capable of learning new physical regularities and can rationally incorporate this information with sensory data. We demonstrate that through multi-day exposure to non-Newtonian billiard ball collisions, the visual system can gradually relearn the internalized regularities used to modulate motion perception. Subjects were trained in a realistic 3D virtual environment and tasked with intercepting a launched ball. The launched ball moved along various deflection angles which all deviated from physics in a consistent, law-like manner. To assess subjects internalized visual predictions of object dynamics, we tested their ability to make absolute judgments pertaining to the launched ball's deflection angle before and after training. Prior to non-Newtonian training, subject's perceptual responses were similar to those found in Deeb et al. (2021), wherein subject's responses reflected a rational inference combining a sensory estimate based on retinal image data with a Newtonian prediction based on pre-collision information. After the two consecutive days of training with new physical regularities we found a significant shift in participant's responses toward the trained deflection angles. This however was not found in our control group who were trained with Newtonian stimuli. Thus, our results indicate that adaptive physical mappings, or priors, can be involved in motion perception and these mappings are not crystallized, but can be altered by experience.

11:30 am

Dynamics of category-level statistical learning from intracranial recordings in visual cortex

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We live in a highly structured world, repeatedly encountering the same objects, people, and places in a reliable fashion. Our mind is deftly attuned to such structure, quickly extracting spatial and temporal regularities via statistical learning. Yet in natural settings, even regular visual input is not identical across repeated experiences and we must learn to extract stable properties across noisy, idiosyncratic instances. Behavioral studies have provided evidence that statistical learning can abstract over such noise to represent high-level regularities. However, these studies relied on separate tests after exposure, raising the possibility that some abstraction may occur through inference across instances at test rather than through online integration during statistical learning. Here we leveraged the spatiotemporal resolution of human intracranial EEG to test whether category-level regularities can be learned online. Patients with epilepsy were exposed to a rapid continuous stream of scene images that were all trial-unique. In the Structured block, the categories of these scenes were paired (e.g., beach-mountain), whereas in the Random block, scenes from other categories were presented in a random order, preventing category-level regularities. Using frequency tagging, we found robust synchrony at the frequency of the image presentation, reflecting neural entrainment to visual stimuli. In the Structured but not Random block there was additionally synchrony at half of the image frequency, reflecting the (learned) boundaries of the category pairs. Critically, this category pair synchrony emerged even though the images differed at the exemplar level, providing online evidence for category-level statistical learning. Using multivariate pattern classification, we further found that paired categories came to be represented more similarly even when presented individually. Specifically, images from the first category in a pair resulted in neural evidence for both the first and second category. These data provide insight into the dynamics and representational changes underlying abstraction during statistical learning.

Acknowledgements: NSF GRFP; NIH R01 MH069456; CIFAR

11:45 am

Substantial changes in global brain processing related to face perception in body dysmorphic disorder patients by training on low spatial frequency components in faces

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Holistic processing plays an important role in face perception. In this study, to better understand the role of processing of low spatial frequency components in face perception, we trained to increase the sensitivity of low spatial frequency components in patients with body dysmorphic disorder (BDD). BDD patients suffer from distressing occupation of slight defects in their appearances including faces and are deficient in holistic processing. BDD patients (N = 9) and healthy

control subjects (N = 10) performed a 2IFC detection task on face images with only low-spatial frequency components over 6 days. During the pre- and post-tests, subjects' BOLD activity was measured with fMRI while subjects performed the 2IFC detection tasks on both faces and houses with each of the low and high spatial-frequency components. We obtained the following training effects. First, both BDD and control groups showed comparable improvements on detecting face images with the low spatial frequency components. Second, only in the BDD group, BOLD activity decreased in the temporoparietal junction (TPJ) in the dorsal face processing pathway. Third, in the BDD group, the dominance of BOLD activity in the fusiform face area (FFA) in the ventral face processing pathway switched from the left to right hemispheres. In the control group, the dominance in FFA switched from right to left hemispheres. Fourth, in the BDD group, the functional connectivity (FC) between the TPJ and occipital face area (OFA) in the ventral pathway increased, while the FC between the left and right FFA decreased. Finally, BOLD activity did not change in the early visual areas for BDD and control groups. These results indicate that learning to improve a task involving low spatial frequency components of faces is associated with substantial changes of face processing in the brain, suggesting a fundamental role of low spatial frequency in face processing.

Acknowledgements: NIH R01EY027841, R01EY019466 (to TW), R21EY028329 (to YS), and United States - Israel Binational Science Foundation BSF2016058 (to TW).

Talk Sessions >

Attention: Models and mechanisms

Friday, May 21, 12:30 - 2:00 pm EDT, Talk Room 1 **Join Zoom Webinar**

Moderator: Joo-Hyun Song, Brown University

12:30 pm

A unifying framework for understanding the factors of visual-attentional processing

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Introduction: There has been no systematic framework that describes the factors of visual-attentional processing. For example, if a type of stimulus is processed efficiently in the visual search, will it also be processed efficiently in the change detection? Methods: Across a broad range of stimulus types and tasks (16 stimulus types × 26 tasks, 1744 observers in total), the present study employed an individual-item differences analysis to extract the factors of visual-attentional processing. The 26 tasks were change detection, long exposure change detection, ensemble change, ensemble matching, feature-based selection, feature counting, feature VWM change, feature VWM probe, grouping, global grouping, location-based selection, difficult location-based selection, monitoring, high-level motion, low-level motion, pattern comparison, previewed pattern comparison, perceptual discrimination, pop-out, saliency-based selection, temporal order, texture segregation, visual search, temporal visual search, VWM encoding, VWM probe. Results: Data of the 26 tasks are in the form of either exposure duration thresholds or accuracies. The reliabilities of all 26 tasks (Cronbach's α) were very high (in the range of 0.973 to 0.992). The data set (in the form of a 16 × 26 matrix) was then analyzed by a Principal component analysis. Three orthogonal factors were identified and they can be labeled respectively as featural, visual, and spatial strengths. Apart from one exception (low-level motion), the FVS 2.0 framework accounts for the vast majority (95.4%) of the variances in the 25 tasks. Conclusion: The three factors provide a unifying framework for understanding the relationship between stimulus types as well as those between tasks. Besides, the role of preattentive features seems to be rather different from the traditional view: visual features are general-purpose, exclusive, innate, constancy-based, and keyword-like. It seems that the features are conscious-level keywords generated by the specific brain area of V4 and/or IT and then used by all other brain areas.

Acknowledgements: The work was supported by two grants from the Research Grants Council of the Hong Kong SAR, China (CUHK 14617615, 14128016).

12:45 pm

Neuronal Population Tuning Statistics to Target and Cues for a feed-Forward Convolutional Neural Network that Learns to Covertly Attend

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Introduction: Attentional effects on perception, once thought to be exclusive to primates, have been more recently measured in simpler organisms such as fruit flies, dragonflies, and honeybees (Nityananda 2016). We investigate whether a simple convolutional neural network (CNN) trained to maximize the detection of a target in a 2-location yes-no task (Posner cueing) results in human-like cueing effects. We analyze individual neurons in the network to understand how they extract and integrate target and cue information. Methods: We trained a CNN on 6000 images containing oriented lines embedded in noise. A box cue co-occurred with the target on 80 % of the trials. The CNN consisted of two convolution layers, each followed by max-pooling, followed by a dense layer, and an output layer with 2 neurons. We evaluated human and CNN performance for a Posner cueing task with varying contrast of a peripheral box cue. We then extracted responses of each neuron to these images and calculated neuron-specific cueing effects (areas under the ROC for valid vs. invalid cues). Results: The CNN trained to optimally detect the target results in a cueing effect comparable to humans and an optimal Bayesian model. Nineteen percent of the neurons in the dense layer showed positive and negative cueing effects with varying degrees (mean = 0.02; standard deviation = 0.10). Neurons with cueing effects detect both the target and the cue in isolation. The weights between the dense neurons and the two output neurons are correlated ($r=-0.64$, $p<0.0001$; $r=0.58$, $p=<0.0001$) with the neuron-specific cueing effects. The convolution layer neurons are retinotopic, while the dense layer neurons are not. Conclusion: Our results show that a simple neural network can learn to utilize cues in a similar manner as humans and establish biologically-plausible architectures and neuronal population properties to integrate target and cue information.

1:00 pm

Learned suppression is based on a proactive mechanism

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In learned suppression, repeated exposure to a specific salient singleton distractor color during visual search leads to a learned ignoring of the otherwise strong bottom-up signal from the distractor. One remaining question is whether this ignoring is based on a pre-search preparatory suppression of the learned color, or a reactive mechanism after attention is captured by the salient distractor during visual search. Previous research has focused on responses to the distractor during search, making it impossible to know if the effects are based on a preparatory suppression. Here, we use SSVEP to measure the pre-search response to the learned distractor color compared to other colors. The neural response to the learned distractor color was suppressed compared to the other colors, providing the first evidence that the mechanism of learned distractor suppression is present in the pre-search period. This result is in line with the predictions of a proactive color-specific suppression in learned suppression.

Acknowledgements: R15EY030247

1:15 pm

Revealing the effects of temporal orienting of attention on response conflict using continuous movements

Melisa Menceloglu[1,2], Satoru Suzuki[2], Joo-Hyun Song[1]; [1]Brown University, [2]Northwestern University

Orienting attention in time enables us to prepare for forthcoming perception and action (e.g. estimating the duration of a yellow traffic light when driving, approximating when to swing at a tennis ball). While temporal orienting can facilitate performance on simple tasks, its influence on complex tasks involving competing response choices is unclear. Here, we adapted the Flanker paradigm to a choice reaching task where participants used a computer mouse to reach to the left or right side of the screen as indicated by the central arrow presented with either the congruent or incongruent flankers. We assessed the effects of temporal orienting by manipulating goal-driven temporal expectation (based on probabilistic variations in target timing) and stimulus-driven temporal priming (based on sequential repetitions versus switches in target timing). We tested how temporal orienting influenced the dynamics of response conflict resolution. Recent choice reaching studies have indicated that under response conflict, delayed movement initiation captures the response threshold adjustment process, whereas increased curvature toward the incorrect response captures the degree of coactivation of the response alternatives during the controlled response selection process. Both temporal expectation and temporal priming reduced the initiation latency regardless of response conflict, suggesting that both lowered response thresholds independently of response conflict. Notably, temporal expectation, but not temporal priming, increased the curvature toward the incorrect response on incongruent trials. We further observed a complementary relationship between the response threshold adjustment and controlled response selection processes of response conflict resolution as shorter initiation latencies predicted greater curvature on incongruent trials, controlling for temporal orienting. These results suggest that temporal orienting generally increases motor preparedness, but the goal-driven mechanisms of temporal orienting particularly interferes with response conflict resolution, potentially through its strong influence on response thresholds. Overall, our study highlights the interplay between temporal orienting and cognitive control in goal-directed action.

Acknowledgements: This study was supported by NSF BCS 1849169 to J.H.S

1:30 pm

Attentional modulation of the population contrast response function within human visual cortex

Ilona Bloem[1,2] ibloem@nyu.edu, Jasmine Pan[2], Sam Ling[2]; [1]New York University, Department of Psychology, [2]Boston University, Psychological and Brain Sciences

While animal and psychophysical studies suggest that attention can enhance visual processing by multiplicatively increasing the gain of an attended item, human fMRI studies instead report that attention modulates overall responsivity, and does not seem to interact with stimulus intensity. A potential reason for this disparity in results between the different methods is that population-based measurements using fMRI find predominantly linear contrast response functions, lacking response saturation. Recent work from our lab has illustrated that leveraging adaptation allows for reliable measurements of saturating contrast response functions. Here, we sought out to test how attention modulates the population contrast response function (pCRF), when we are able to capture the nonlinear relationship between stimulus contrast and BOLD response. We used an fMRI adaptation paradigm to measure BOLD responses in early visual cortex (V1-V3). Participants viewed full-field stimuli displays composed of radially oriented, cortically magnified gratings varying in contrast throughout a scan (9 contrast levels, spaced between 0-88% Michelson contrast). Participants were cued before the onset of each contrast presentation to either covertly attend to the stimulus, performing a color probe detection task, or to perform a demanding task at fixation, drawing attention away from the stimulus. Using deconvolution analyses to estimate the BOLD response for each contrast level, we were able to capture nonlinear pCRFs of individual voxels within each visual area. Importantly, we found that the influence of attention was best summarized by a combination of an additive and contrast gain modulation. In sum, our results demonstrate that attentional modulation of the pCRF as measured with fMRI is not purely additive, but additionally exhibits multiplicative gain increases.

Acknowledgements: NIH EY028163

1:45 pm

Information Value Underlies Priority in Feature Based Attention

Phillip Witkowski[1,2] pwitkowski@ucdavis.edu, Joy Geng[1,2]; [1]University of California, Daivs, [2]Center for Mind and Brain, University of California, Davis

Recent research on attentional templates suggests that representations of target items held in WM are not static representations of past stimuli, but dynamic representations that prioritize task-relevant information in the environment. However, complex environments may obfuscate which source of information is best to prioritize, meaning the visual system must make judgments about the predictability of information (information value) to efficiently allocate attention. How these these predictions are generated and how they relate to the allocation of attention are still poorly understood. To determine the relationship between information value and feature based attention, we designed an online search task for a target object defined by an orientation and color. At the start of each trial, participants (N=240) were cued with the most likely features of the target, but knew these features could change to any within a distribution of possible values. Target color was always sampled from a distribution with high uncertainty (SD=55), but the target orientation was drawn either low-variability (SD=10), medium-variability (SD=25), or high-variability (SD=40) distribution. A separate group of participants were allocated to a control condition each feature was drawn from identical t-distributions with low-variability (SD=10). Interleaved were 18 probe trials which asked participants to rate the likelihood of possible targets, gauging participants knowledge of the underlying feature distribution. Results showed that attention to each target target orientation was enhanced when its relative information value was high, while color was suppressed, mirroring participants knowledge of each feature distribution. Attention to either feature returned to baseline when the information values were approximately equal. These results point to a critical role of information value in feature based prioritization in the attentional template.

Talk Sessions >

3D Perception and Stereopsis

Friday, May 21, 12:30 - 2:00 pm EDT, Talk Room 2 Join Zoom Webinar

Moderator: Michele Rucci, University of Rochester

12:30 pm

3D cue remapping resulting from experienced variability of scene parameters

James Wilmott[1] jpwilmott3@gmail.com, Jovan Kemp[1], Fulvio Domini[1]; [1]Brown University

Multiple cues, such as texture gradients and binocular disparity, are combined to derive 3D scene structure. Perceptual experience changes the mapping between cue values and 3D estimates, termed here 3D cue remapping. Prominent Bayesian models of cue combination assume that 3D cue remapping occurs via changes in relative reliabilities, resulting in 'cue reweighting' (Ernst, Banks & Bültoff, 2000). An alternative model, termed Intrinsic Constraint (IC; Domini & Vishwanath, 2020), postulates the existence of deterministic image operators for each cue that do not estimate reliability. Instead, these operators are tuned to ideal scene parameters learned through repeated interactions with the environment. For example, the ideal material composition of an object yields a well-defined texture gradient. IC combines cues through a function that maximizes the response to 3D properties while minimizing the influence of scene parameters unrelated to 3D shape. This is achieved by scaling each cue by the variability of the corresponding scene parameter within the natural environment; 3D cue remapping occurs when the visual system changes its estimate of this variability. Here, we reasoned that repeated interactions with texture- and disparity-defined 3D objects varying in material composition should lower the contribution of texture gradients to 3D perception, even when cues are congruent and no mismatch between haptic and visual information is present. Before and after a training session, we determined the relative contribution of monocular and binocular cues. During training, observers repeatedly grasped cue-consistent 3D half-ellipsoids, always receiving the appropriate haptic feedback. However, three material compositions determined in a previous experiment were randomly selected on each trial, artificially expanding the range of variation of texture information. As predicted, the contribution of monocular information was significantly reduced after training. These results suggest cue contributions to estimated depth can be dynamically adjusted according to experienced variability of scene parameters, rather than reliability.

12:45 pm

Causal inference contributes to biases in depth perception due to object motion

Ranran French[1], Gregory DeAngelis; [1]University of Rochester

It is crucial for animals to accurately judge the depth of moving objects. During observer translation, the relative image motion between stationary objects at different distances, known as motion parallax (MP), provides important depth information. However, when an object also moves relative to the scene, the computation of depth from MP is complicated by the object's independent motion. Previously we have shown that, when humans view a moving object during visually simulated self-motion, they show a systematic bias in perceived depth that depends on object and self-motion directions, as well as object speed. Here, we examined the origins of this depth bias by directly asking subjects to report whether or not an object moves relative to the scene while simultaneously performing a depth discrimination task. Naïve human subjects viewed a virtual 3D scene consisting of a ground plane and stationary background objects, while lateral self-motion was simulated by optic flow. A target object, lying above the ground plane, could be either stationary or moving laterally at different velocities. Subjects were asked to judge the depth of the target object relative to the plane of fixation, as well as whether they thought the object was moving independently relative to the scene. For object speeds at which subjects report the object to be moving ~50% of the time, they show biases in perceived depth that depend on their report about object motion. This dependence is more prominent when the object is viewed monocularly, such that depth cues are less reliable. Our results indicate that perceived depth based on MP depends systematically on subjects' causal inference regarding scene-relative object motion, consistent with predictions of a

Bayesian observer model.

1:00 pm

Interplay between body reflectance and shape to reduce cues to shading in living animal

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Many animals, including ourselves, use shading as a cue to shape. Darker coloration on the side of the body facing the light (‘countershading’) is widespread in the animal kingdom and has long been assumed to offer camouflage by obliterating shape-from-shading cues. The pigmentation counterbalances the gradient of illumination on the body by adopting a darker reflectance on the parts that receive more light. However, while it is clear that there must be an interplay between animal shape and reflectance to deliver the best countershading camouflage, the specific contribution of shape to countershading camouflage has been never studied. Here we explored whether body shape, along with reflectance, contributes to reduction of shading cues in several species of caterpillar. We combined stereo photography and light field recovery to measure simultaneously the shape and reflectance of living caterpillars from six species of moths (N = 84, mean = 14, SD = 8.1), three of which are countershaded. If shape and reflectance are both important, then swapping either on a countershaded species should increase visibility. Using three-dimensional modelling of light, body shape and reflectance interaction, we ‘swapped’ species’ shapes and reflectance patterns and computed the visibility of the resulting ‘hybrids’ under several ecologically relevant lighting conditions. We found that not only reflectance, but the tight interplay between reflectance and shape drove visibility, particularly for some countershaded species. For these, adopting the shape or the reflectance of another species resulted in a significant increase in shading cues, in visibility, and therefore in the likelihood of predation. Taken together, our data suggest that some countershaded species exhibit a co-adaptation of shape and reflectance to minimize visibility to predators, opening a new avenue of research that considers body shape alongside body reflectance as a fundamental factor underlying how coloration acts as visual camouflage.

1:15 pm

Fixational eye movements contribute to stereopsis

Janis Intoy[1-2] jintoy@bu.edu, Michele A Cox[2], Emin Alicic[2], Jonathan D Victor[3], Martin S Banks[4], Michele Rucci[2]; [1]Boston University, [2]University of Rochester, [3]Weill Cornell Medical College, [4]Univeristy of California, Berkeley

Humans use differences in the visual input to the two eyes to extract depth information, a process known as stereopsis. The visual system is exquisitely sensitive to these differences and able to detect disparities smaller than the photoreceptor spacing. This accomplishment is even more remarkable considering that the eyes drift incessantly during fixation, resulting in retinal image motions that are largely uncorrelated in the two eyes. Since these drifts cover tens of photoreceptors and continually change the correspondence between retinal points, one might expect they would hinder stereopsis. However, we hypothesized that the temporal modulations they produce are in fact beneficial. To test this, we examined the consequences for stereopsis of the retinal image motion resulting from eye drifts. Subjects (N=7) were asked to discriminate the orientation (±10deg) of a sinusoidal depth corrugation (1 cycle/deg) created by modulating the disparity of random dot stereograms. Combination of binocular high-resolution eye-tracking with real-time gaze-contingent display enabled precise control of the retinal stimulus delivered to each eye. We show that fixational eye movements are beneficial to stereopsis. In all observers, stereoscopic discrimination was greatly impaired when the images in both eyes were continually adjusted to counteract the visual consequences of eye drifts and eliminate retinal image motion (a three-fold difference in d’; p=0.03, signed-rank test). To determine whether this effect originated from a monocular reduction in contrast sensitivity or temporal modulations in binocular disparity, we selectively eliminated the version and vergence components of retinal image motion. The resulting signals conveyed similar power in their luminance modulations but only vergence motion affected disparity. Discrimination was normal in the presence of vergence motion and greatly impaired in its absence. These findings extend dynamic theories of vision to depth perception. They suggest that stereoscopic perception relies on transient disparity signals produced by fixational vergence eye movements.

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1:30 pm

Scaling stereoscopic depth through reaching

Brittney Hartle[1] brit1317@yorku.ca, Laurie Wilcox[1]; [1]York University

Depth estimation from stereopsis is biased under many viewing scenarios and for a range of estimation methods, particularly for virtual stimuli. These distortions are often attributed to misestimates of viewing distance that result in incorrect scaling of binocular disparity. The majority of research on depth scaling has considered only visual cues to distance. However, we do not just look at the world, we interact with objects and in this way may have access to proprioceptive cues to distance. There is evidence that stereopsis aids actions such as prehension; is the reverse also true? We assessed the impact of proprioceptive distance from arm's reach on stereopsis using a ring game that is contingent on accurate absolute distance perception. Observers used hand controllers and their index finger to move rings onto a peg in a virtual environment. They completed the task as quickly as possible while avoiding touching the rings to the peg (errors were signalled via controller vibration). After each block of 5 trials observers were given feedback regarding their completion time and accuracy. To evaluate the impact of this proprioceptive experience we assessed depth magnitude estimation before and after completion of the ring task. Observers were asked to estimate the depth between a rectangle and a reference frame located at the same distance as the peg in an otherwise blank field. We found that depth estimation accuracy and scaling improved with experience. Importantly, in a follow-up experiment we found that this improvement was contingent on performing the reach. Consistent with the assumption that observers underestimate absolute distance, we found that most ring-placement errors were due to underreaches. We conclude that the improvement in depth estimation seen here reflects a cross-modal calibration of visual space that is underappreciated, but potentially important for everyday interactions.

1:45 pm

Revealing Differential Mechanisms of Absolute vs. Relative Disparity Encoding in Human Extrastriate Visual Cortex and Impacts of Amblyopia on Them

Shahin Nasr[1,2] shahin.nasr@mgh.harvard.edu, Bryan Kennedy[1], Amanda Nabasaliza[1,3], Peter Bex[4], David G. Hunter[3,5], Roger B.H. Tootell[1,2]; [1]Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, [2]Department of Radiology, Harvard Medical School, [3]Department of Ophthalmology, Boston Children's Hospital, [4]Department of Psychology, Northeastern University, [5]Department of Ophthalmology, Harvard Medical School

Background: Absolute and relative disparity cues are crucial for coarse and fine depth encoding, respectively. In human and non-human primates (NHPs), relative disparity cues are preferentially encoded within thick-type cortical columns, distributed within extrastriate visual cortex. In NHPs, electrophysiological evidence for absolute disparity encoding is limited to areas V1 and MT. However, neural mechanisms underlying absolute disparity encoding in human extrastriate cortex are largely unknown. This information is crucial in terms of defining the cortical sites affected by amblyopia, a developmental disorder caused by disruption of symmetric binocular visual input early in life, with significant impact on stereopsis. Methods: We used high resolution fMRI (7T) to test the response to absolute vs. relative disparity in seven individuals with normal vision, plus five amblyopic (3 strabismic and 2 anisometropic) individuals with impaired stereopsis (stereoacuity >250 arc sec; randot test). Stimuli were generated using random dot stereograms. In each individual, motion- and color-selective clusters were localized within areas V2, V3 and V3A based on independent scans (see also Kennedy et al. abstract). Results: In addition to area MT, absolute disparity evoked a significant response within V3 and V3A (but not V2) motion-selective clusters. This activity was significantly stronger than the response to relative disparity. Outside motion-selective clusters, those clusters that showed a significant response to relative disparity showed a weaker response to absolute disparity. Color-selective clusters did not show any significant response to either relative or absolute disparity. Motion-selective clusters were detected across V3 and V3A in amblyopic (as in non-amblyopic) individuals (see also Kennedy et al.). However, in amblyopic individuals, we did not find any significant response to absolute/relative disparity within/outside motion-selective clusters. Conclusion: Absolute and relative disparity are encoded within different neuronal clusters across areas V3 and V3A. Development of absolute and relative

disparity encoding mechanisms are impaired by amblyopia.

Acknowledgements: This work was supported by NIH NEI (grants R01EY026881 and R01EY030434), and by the MGH/HST Athinoula A. Martinos Center for Biomedical Imaging. Crucial resources were made available by a NIH Shared Instrumentation Grant S10-RR019371.

Attention: Features, objects, salience

Saturday, May 22, 10:30 am - 12:00 pm EDT, Talk Room 1 Join Zoom Webinar

Moderator: Dominique Lamy, Tel Aviv University

10:30 am

The time-course of incentive salience in naturalistic human vision

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When visual objects are imbued with reward—usually in the form of monetary benefits—they become salient. As a result, they draw attention in a way not accounted for by traditional notions of top-down strategic goals and bottom-up physical salience. This ‘incentive salience’ has largely been investigated in experiments employing synthetic stimuli like geometric shapes characterized by saturated color. Much less is known about how incentive salience impacts processing of complex real-world stimuli. Here, we investigate the impact of financial reward on selective processing of natural categories of visual stimuli (cars, trees, people) presented in images of real-world scenes. We employed an experimental design in which one category of visual object was consistently rewarded when it was the target of search but could appear as an irrelevant distractor when search was for a different object category. Our hypothesis was that rewarded targets would acquire salience, and thus need to be visually suppressed when they acted as distractors. To test this, we used the N2pc and Pd ERP components – which track visual selection and suppression, respectively – to index processing of targets and distractors in our scene stimuli. Results show that suppression of reward-associated real-world distractors emerges rapidly. Reward thus appears to bind to categories of visually heterogenous naturalistic stimuli categories, creating the need for strong suppression when examples of reward-associated categories must be ignored.

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10:45 am

Attentional prioritization for historical traces of agency

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Among the most important stimuli we can perceive are other agents. Accordingly, a great deal of work has shown how visual attention is prioritized not just for certain lower-level properties (e.g. brightness or motion) but also for *social* stimuli (e.g. our impressive efficiency at detecting the presence of people in natural scenes). In nearly all such work, the relevant agents are explicitly visible — e.g. in the form of bodies, faces, or eyes. But we can also readily perceive the *historical traces* that agents may leave behind. When walking along a hiking trail, for example, a stack of rocks along the side of the path may elicit the immediate strong impression that an agent had been present, since such configurations are exceptionally unlikely to be produced by natural processes. Does visual processing also prioritize such 'traces of agency' (independent from properties such as order and complexity)? We explored this using visual search, in scenes filled with two kinds of block towers. In Agentic Trace towers, the blocks were slightly misaligned (as would only likely occur if they had been intentionally stacked by an agent), while in Non-Agentic towers they were perfectly stacked (in ways an agent would be unlikely to achieve). Across multiple experiments, observers were both faster and more accurate at detecting Agentic Trace towers (in arrays of Non-Agentic towers), compared to detecting Non-Agentic towers (in arrays of Agentic Trace towers). Critically, this difference was stronger than when the same stimuli were presented in ways that equated order and complexity (e.g. with additional vertical spacing), while eliminating perceived traces of agency. This attentional prioritization for "agency without agents" reveals that social perception is not just a response to the superficial appearances of agents themselves, but also to the deeper and subtler traces that they leave in the world.

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11:00 am

Spatial cueing effects do not always index attentional capture: Evidence for a Priority Accumulation Framework

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In visual search, improved performance when a target appears at a recently cued location is taken as strong evidence that attention was shifted to this cue. Here, we provide evidence challenging the canonical interpretation of spatial-cueing (or cue-validity) effects and supporting the Priority Accumulation Framework (PAF). According to PAF, attentional priority accumulates over time at each location until the search context triggers selection of the highest-priority location. Spatial-cueing effects reflect how long it takes to resolve the competition and can thus be observed even when attention was never shifted to the cue. Here, we used a spatial-cueing paradigm with abruptly onset cues and search displays varying in target-distractor similarity. We show search performance on valid-cue trials deteriorated the more difficult the search, a finding that is incompatible with the standard interpretation of spatial-cueing effects. By using brief displays (Experiment 1) and by examining the effect of search difficulty on the fastest trials (Experiment 2), we invalidate alternative accounts invoking post-perceptual verification processes (Experiment 1) or occasional failures of the onset cue to capture attention (Experiment 2). In Experiment 3, we used a combination of the spatial-cueing and dot-probe paradigms. We show that the events that occurred in both the cue and search displays affected attentional distribution, and that the relative attentional priority weight that accumulated at the target location determined how easily the competition was resolved. These findings fully support PAF's predictions.

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11:15 am

The target similarity conundrum in rapid serial visual presentation

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To deal with rapidly changing visual information, the brain has developed an attentional system that optimises our perception to detect important changes. To probe this attentional system, researchers often use rapid serial visual presentation (RSVP) paradigms. In a two-target RSVP, participants are asked to report two targets (T1/T2) that are embedded among multiple distractors in a stream of stimuli. In a well-known RSVP phenomenon, known as repetition blindness (RB), T2 is often unreported when targets are repeated. This effect has been argued to be due to a memory, rather than a perceptual, failure. In a previous study, we measured multivariate brain representations throughout the visual hierarchy and showed that the more similar targets were in high-level regions, the more likely participants were to miss T2, extending previous findings of RB. In contrast, when targets were similar in low-level regions (e.g. V1), performance on T2 increased. In the current study, we aim to resolve this conundrum and hypothesise that V1-similarity between targets increases the rate of evidence accumulation for T2. Based on a large high-resolution functional magnetic resonance imaging dataset (Natural Scenes Dataset, http://naturalscenesdataset.org) we constructed RSVP trials with low, mid, and high V1-similarity between targets. We then asked participants to memorise T1 while making a speeded animacy judgment on T2. We employed drift-diffusion modelling on the reaction time distribution for T2 responses to show that evidence accumulation is positively modulated by V1 similarity. This effect was present even after filtering away trials where T1 was an animal, meaning it cannot be explained by any selection bias of images in either category. In contrast to previous RB theories, associated with repetitions in the task-relevant domain, V1 similarity not only increases T2 performance but appears to be related to pre-conscious processes.

Acknowledgements: This research was supported by an NIH P41 EB027061, NSF IIS-1822683, and NSF IIS-1822929 to K. K, and a ERC Starting Grant ERC-2017-StG 759432 to I. C.

11:30 am

Individual differences in the temporal dynamics of object-based attention

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Attention can be focused on specific locations in our visual field (space-based attention), but also spreads along objects (object-based attention). However, space- and object-based effects are prone to large individual differences, and whereas space-based effects are stable, object-based effects are not as prevalent as previously assumed. In the current study, we investigate whether the low prevalence of object-based effects is related to individual differences in the temporal dynamics of attentional selection. We measured space- and object-based effects on reaction times for individual participants in a two-rectangle discrimination task, in which cue-target intervals were varied between 50 and 600 ms. We used bootstrapping to investigate cue-to-target intervals with maximal object-based effects, and fast Fourier transform (FFT) to investigate the rhythmic sampling of visual space within and between objects. Whereas overall, space-based effects were robust and stable across all cue-to-target intervals for most participants, object-based effects were small and were only found for a small subset of participants. In the frequency domain, our results confirm rhythmic patterns of visual-target detection within (8 Hz) and between objects (4 Hz and 8 Hz). However, we found large inter-individual variability in sampling rhythm phases and no consistent phase relationship. Taken together, the low-prevalence of object-based effects cannot be explained by inter-individual variability in the temporal dynamics of attentional selection. Our results provide strong evidence for considering individual variations in developing theories of visual attention.

Acknowledgements: This work was supported by a China Scholarship Council (CSC) scholarship to HL (201906360170).

11:45 am

The Normalization Model Captures the Effects of Object-based Attention in the Human Visual Cortex

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The normalization model of attention has been proposed as a unifying framework to account for various effects of attention in the visual cortex, and its success in predicting neural responses has been documented in primate electrophysiology studies. Here, using a human fMRI study, we investigated whether the normalization model can predict attentional modulations when participants attend to an object in a cluttered scene. We used a blocked-design paradigm in which half-transparent stimuli from the two categories of human bodies and houses were presented either in isolation or in pairs. A cue at the beginning of the block indicated the attended object. When paired, stimuli were superimposed to enforce object-based attention. We focused on the object-selective regions lateral occipital cortex (LOC) and posterior fusiform area (pFs), and the category-selective regions extrastriate body area (EBA) and parahippocampal place area (PPA) and determined the preferred and null stimuli for each voxel in each region. Results showed that shifting attention from the preferred to the null stimulus significantly reduced voxel responses in all these regions. Also, the effect of the unattended stimulus on the responses depended on voxel selectivity for that stimulus, with the unattended preferred stimulus having larger effects on the responses than the unattended null stimulus. We modeled voxel responses in different attentional conditions using a linear, a weighted average, and a normalization model. Results indicated that while the linear and the weighted average models were better than chance in predicting the responses, the normalization model had significantly better predictions than the other two models in all regions and especially captured the effect of voxel selectivity on the attentional modulations. These results suggest that when attending to objects in a cluttered scene, the responses in the object selective cortex are determined by divisive normalization.

Acknowledgements: visual attention, normalization, fMRI, category selectivity

Face Perception: Models and mechanisms

Saturday, May 22, 10:30 am - 12:00 pm EDT, Talk Room 2 Join Zoom Webinar

Moderator: Martin Giese, Tübingen

10:30 am

Neural models for the cross-species recognition of dynamic facial expressions

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Dynamic facial expression recognition is an essential skill of primate communication. While the neural mechanisms to recognize static facial expressions has been extensively investigated, they remain largely unclear for dynamic facial expressions. We studied plausible neural encoding mechanisms, exploiting highly controlled and realistic stimulus sets generated by computer graphics, which are also used in electrophysiological experiments. METHODS: Combining mechanisms from physiologically plausible neural models for the recognition of dynamic bodies (Giese & Poggio, 2003), static faces (Giese & Leopold, 2005) and architectures from computer vision (Simonyan et al., 2014), we devised models for the recognition of dynamic facial expressions. The first model is example-based, and encodes dynamic expressions as temporal sequences of snapshots, exploiting a sequence-selective recurrent neural network. The second model exploits norm-referenced encoding, where face-space neurons are tuned to the differences between the actual stimulus frame and a reference face, the neutral facial expression. The dynamic expressions are recognized by differentiating the responses of these face-space neurons. We tested the models with high-quality human and monkey avatars, animated with motion capture data from both species, controlling expression by motion morphing. RESULTS: Both models recognize reliably dynamic facial expressions of humans and monkeys. However, the predicted behaviour of face-tuned neurons is very different for both models. The norm-referenced model shows a highly gradual, almost linear dependence of the neuron activity with the expressivity of the stimuli, while the neurons in the example-based model show very limited capability of generalization to expressions with varying strength. We also explored if the models explain the human capability of humans to recognize human expressions on monkey faces (Taubert et al. 2020). CONCLUSIONS: The two physiologically plausible models accomplish the recognition of dynamic faces and make distinguishable predictions for physiological experiments, where norm-referenced encoding might support transfer of expression recognition across different head shapes.

Acknowledgements: This work was supported by HFSP RGP0036/2016, ERC 2019-SyG-RELEVANCE-856495 and NVIDIA Corp. MG was also supported by BMBF FKZ 01GQ1704 and BW-Stiftung NEU007/1 KONSENS-NHE. RS, SS, PD, and PT were supported by a grant from the DFG (TH 425/12-2)

10:45 am

Biologically plausible illumination-invariant face representations

Dylan D. Doblar[1] ddoblar@mit.edu, Katherine M. Collins[1], Bernhard Egger[1], Tomaso Poggio[1]; [1]Massachusetts Institute of Technology

Humans possess a remarkable ability to identify objects — and faces in particular — under highly variable conditions. The invariance hypothesis (Leibo et al., 2015) posits that the goal of the human ventral visual system is to learn representations that are invariant to identity-preserving transformations. One computational approach to learn such representations is the templates-and-signatures model proposed by Liao et al. (2013). The model measures similarities between template images and unseen query images to produce discriminative and invariant signatures. From a small number of template examples, the model can learn invariance to group transformations (e.g., scaling, translation, and in-plane rotation) for new object classes, whereas object-class-specific templates are required for non-group transformations (e.g., pose). Here, we probe the capacity of this approach to handle variation in illumination — a complex set of non-group transformations — on a face verification task. A 3D morphable face model is used to generate

synthetic datasets under both natural and extreme illumination. We benchmark the templates-and-signatures approach against VGG16, a convolutional neural network (CNN), and compare the effects of a generic object-class versus domain-specific learned prior by pre-training VGG16 either on ImageNet or human faces. We find that under natural illumination settings, the templates-and-signatures model effectively solves the face verification task, outperforming both CNN variants. Additionally, the templates-and-signatures model's learned representations are impressively invariant to extreme variations in illumination and generalize best when using natural illumination templates. These invariances hold even with tens of training examples, which is particularly striking behavior relative to the CNNs that have been pre-trained on millions of images. Coupled with its simplicity and its implications for a biologically plausible sequence of class-specific developmental periods for learning invariances, the model's ability to generalize to out-of-distribution illumination settings from few examples lends credence to a templates-and-signatures account of feed-forward object recognition.

Acknowledgements: We thank Qianli Liao for his advice on how to implement the templates-and-signatures model. This work was funded in part by the Center for Brains, Minds and Machines (CBMM), NSF STC award CCF-1231216. B. Egger is supported by a PostDoc Mobility Grant, Swiss National Science Foundation P400P2 191110.

11:00 am

Decoding real-world visual recognition abilities in the human brain

Simon Faghel-Soubeyrand[1,4] simonsoubeyrand@gmail.com, Meike Ramon[2], Eva Bamps[3], Matteo Zoia[2], Jessica Woodhams[4], Arjen Alink[5], Frédéric Gosselin[1], Ian Charest[4]; [1]Université de Montréal, [2]Université de Fribourg, [3]KU Leuven, [4]University of Birmingham, [5]University Medical Center Hamburg-Eppendorf

The typical human visual system is able to decipher information about the visual world with impressive efficiency and speed. But not all individuals are equally competent at recognising what is presented to their eyes. Critically, very little is known about the brain mechanisms behind variations in recognition abilities. Here, we ask if interindividual variation in face cognition can be accurately "read" from brain activity, and use computational models to characterise the underlying brain mechanisms. We recorded high-density electroencephalography (EEG) in typical (n=17) and "super-recogniser" participants (n=16; individuals in the top 2% of face-recognition ability spectrum) while they were presented with images of faces, objects, animals, and scenes. Relying on more than 100,000 trials, we trained linear classifiers to predict whether trial-by-trial brain activity belonged to an individual from the "super" or "typical" recogniser group. Significant decoding of group-membership was observed from ~85ms, peaking within the N170 window, and spreading well after stimulus offset (>500ms). Using fractional ridge regression, we extended these findings by predicting individual ability scores from EEG in similar time-windows. Both results held true when decoding from face or non-face stimuli. To better understand the brain mechanisms behind these variations, we used representational similarity analysis and computational models that characterise visual (convolutional neural networks trained on object recognition; CNNs) and semantic processing (deep averaging network trained on sentence embeddings). This computational approach uncovered two representational signatures of higher face-recognition ability: mid-level visual computations (representations within the N170 window and mid-layers of CNNs) and high-level semantic computations (representations within the P600 window and the semantic model). Altogether, our results indicate that an individual's ability to identify faces is supported by domain-general brain mechanisms distributed across several information processing steps, from low-level feature integration to high-level semantic processing, in the brain of the beholder.

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11:15 am

Neural Correlates of Integration Processes during Dynamic Face Perception

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Integrating the spatiotemporal information that is constantly presented by the highly dynamic world around us is essential to navigate, reason, and decide properly. Although this is extremely important in a face-to-face conversation, very little research to date has specifically examined the neural correlates of temporal integration in dynamic face

perception. Our study separates the composite neural correlates of the spatial and temporal integration processes from each other. Thus we provide statistically robust observations about the brain activations that are specific to the temporal integration or specific to the spatial integration. For this purpose, we generate video recordings of neutral faces of individuals and non-face objects, and then frequency tag (modulate contrast in an interlaced manner) the even and odd frames at two specific frequencies (f1 and f2). Here, tagging aims to not only increase the signal-to-noise ratio (SNR) of steady-state visual evoked potentials (SSVEP) but also helps us trace the nonlinear processing at the neural level while the temporally separated and frequency-tagged frames are integrated. To this end, we measure SSVEP as participants view such generated videos, and analyze the intermodulation components (IMs) that are designed to reflect nonlinear processing and indicate temporal integration. A pattern analysis is additionally conducted to quantify the information in SSVEP and assess the statistical robustness of our observations. We show that the medial temporal, inferior and medial frontal areas respond strongly and selectively when viewing dynamic faces. These regions also increase their activation as a function of increasing sequential dynamic information, hence manifesting the essential processes underlying our ability to perceive and understand our social world. Since the generation of IMs is only possible if even and odd frames are processed in succession and integrated temporally, the strong IMs show that the time between frames (1/60=0.016 seconds) is sufficient for temporal integration.

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11:30 am

How motivated do I look? How humans fail and computer vision succeeds in interpreting facial behavior

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An observer’s perception and interpretation of facial behavior of others is prone to error and bias due to attentional bottlenecks, heuristics, and the lack of proper feedback to learn from. Here we investigate an objective approach to the measurement of nonverbal behaviors to infer the motivation levels of webcam-recorded participants that executed an online, structured job interview. First, we implemented and developed artificial intelligence and computer vision algorithms to automatically detect participants’ facial muscle activity and emotional expressions in videos. The extracted facial features served as input to an unbiased, cross-validated model to predict the motivation levels of participants that they introspectively reported after the interview. The motivation judgments by the model outperformed human observers’ unreliable, invalid, and gender-biased judgments. In order to determine motivation, observers correctly pay attention to some of the relevant facial features but, unlike the model, fail to assign correct weights and signs. These findings mark the necessity and usefulness of novel, bias-free, and scientific approaches to observing and judging human behavior.

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11:45 am

Human Detection of Deepfakes: A Role for Holistic Face Processing

Matthew Groh[1] groh@mit.edu, Ziv Epstein[1], Rosalind Picard[1], Chaz Firestone[2]; [1]MIT Media Lab, [2]John Hopkins University

Two of the most significant recent advances in artificial intelligence are (1) the ability of machines to outperform humans on many perceptual tasks, and (2) the ability of machines to synthesize highly realistic images of people, objects, and scenes. Nevertheless, here we report a surprising human advantage at the intersection of these two domains: The ability to detect Deepfakes. Deepfakes are machine-manipulated media in which one person’s face is swapped with another to make someone falsely appear to do or say something they did not — and it is of major theoretical and practical importance to develop methods that can tell Deepfakes from authentic media. Here, we pit the winning computer vision model from the Deepfake Detection Contest (DFDC) against ordinary human participants in a massive online study enrolling 7,241 people. Participants saw authentic and manipulated videos, and were asked to either (a) select which of two videos is a Deepfake (Experiment 1) or (b) share how confidently they think a video is a Deepfake (Experiment 2). In the two-alternative forced-choice design, the average completely untrained participant outperformed the very best computer vision model. In the single-stimulus design, the average participant outperformed the model on a sample of

politically salient videos but underperformed the model on a sample of DFDC holdout videos. (Though approximately one fourth of participants outperformed the model on the DFDC sample.) Follow-up experiments revealed that holistic face processing partly explains this human edge: When the actors' faces were inverted, misaligned, or occluded, participants' ability to identify Deepfakes was significantly impaired (whereas the model's performance was not impaired for misaligned or occluded videos but impaired for inverted videos). These results reveal a human advantage in identifying Deepfakes today and suggest that harnessing specialized visual processing could be a promising "defense" against machine-manipulated media.

Talk Sessions >

Spatial Vision

Saturday, May 22, 2:30 - 4:00 pm EDT, Talk Room 1 Join Zoom Webinar

Moderator: Andrew Watson, Apple Computer

2:30 pm

Fechner and Stevens can co-exist under Fisher's roof

Jingyang Zhou[1] jyz205@nyu.edu, Lyndon R Duong[2], Eero P Simoncelli[1,2]; [1]Flatiron Institute, [2]New York University

One of the foundations of quantitative perceptual psychology is Weber's observation of the nineteenth century: for many sensory attributes, the amount of just-detectable stimulus perturbation (perceptual threshold) is proportional to stimulus intensity. Fechner proposed that Weber's Law arises from a logarithmic internal representation of these quantities, which when differentiated gives rise to the observed perceptual sensitivity. In apparent contradiction to Fechner's proposed logarithmic relationship, Stevens (1957) found that observers' ratings of perceived stimulus intensity followed a power law, with the power taking on a wide range of values across different stimulus attributes. Attempts have been made to reconcile these two conflicting quantitative accounts of the relationship between perception and stimulus intensity, but the problem remains unresolved, and continues to impede our understanding of the representation and comparison of perceptual quantities. We propose a resolution of this quandary, by separating the effects of both mean and variance of an abstract internal representation of stimuli. We assume that a rating scale, such as that used by Stevens, reflects the mean internal representation of stimulus intensity, but is unaffected by its variability. On the other hand, discrimination thresholds (as captured by Weber's Law) depend on both the mean and variability of that internal representation, a relationship captured by Fisher Information. Stevens' Power Law mapping can be made consistent with Weber's Law by assuming internal noise whose standard deviation scales according to the same power law. This implies that the variance of internal representations must grow as the square of their mean, a super-Poisson property that has been attributed to fluctuations of response gain in sensory neurons (Goris et al 2015, Lin et al 2015). Considering the effects of both mean and variance of the internal representation brings us one step closer to a consistent mechanistic understanding of the established psychophysical observations.

2:45 pm

Identifying and localizing retinal features that predict human contrast sensitivity via deep learning

MiYoung Kwon[1] miyoungkwon02@gmail.com, Rong Liu; [1]Northeastern University

Luminance contrast, the difference in intensity between light and dark regions of an image, is a fundamental building block of human pattern vision. While it is well known that contrast information is first encoded by the center and surround structure of retinal ganglion cell (RGC) receptive fields, relatively little is known about the quantitative relationship between RGCs and psychophysically measured human contrast sensitivity. Here we aimed to predict human contrast sensitivity directly from structural retinal imaging data and to localize retinal features closely linked to contrast sensitivity. Data were collected from a total of 262 eyes including both normal healthy eyes and glaucomatous eyes. For each eye, we obtained cross-sectional retinal images centered on the fovea via Spectral-Domain Optical Coherence Tomography (SD-OCT) and Pelli-Robson contrast sensitivity data. We adopted a deep residual neural network (ResNet) trained on OCT structural images to predict contrast sensitivity. We evaluated the prediction performance of the network. We also extracted attention maps representing the critical features learned by the network for the output prediction. Our results showed that the network produced high prediction performance with the mean square error and the mean absolute error of 0.01 and 0.09, respectively. Importantly, our attention map analysis further revealed that the network utilized the structural information extracted from the thickness features of the Ganglion Cell Layer containing RGC bodies and the Inner Plexiform Layer containing RGC dendritic structures. Particularly, the structural information within the perifoveal region of the retina was most critical to the output prediction, consistent with the notion that RGC receptive fields responsible for processing foveal visual input, are laterally displaced. Our work demonstrates that psychophysically measured human contrast sensitivity can be reliably predicted from retinal structural data alone. Our findings further

highlight a determining role of RGC sampling density for human contrast sensitivity.

Acknowledgements: This work was supported by NIH/NEI Grant R01EY027857 and Research to Prevent Blindness (RPB)/Lions Clubs International Foundation (LICF) low vision research award.

3:00 pm

Topological Smoothing of Retinotopic Maps

Yanshuai Tu[1] yanshuai@asu.edu, Duyan Ta[1], Zhong-Lin Lu[2,3,4], Yalin Wang[1]; [1]Arizona State University, [2]New York University Shanghai, [3]New York University, [4]NYU-ECNU Institute of Brain and Cognitive Science at NYU Shanghai

Retinotopic mapping (RM) is one of the central topics in vision science. Human RM can be obtained by analyzing functional magnetic resonance imaging (fMRI) signals of cortical responses to slowly moving visual stimuli on the retina. It is well-known in neurophysiology that RM is topological (i.e., neighborhood connectivity is preserved). However, the measured RM is often not topological because of the low signal-to-noise ratio and spatial resolution of fMRI. The topological violations make it difficult to precisely quantify properties of retinotopic maps. We developed a topological smoothing method for retinotopic maps. Specifically, we used Beltrami coefficient to define the topological condition, developed a mathematical model to quantify topological smoothing as a constrained optimization problem, and elaborated an efficient numerical method to solve the smoothing problem. The method can be applied to V1, V2, and V3 simultaneously. We evaluated the performance of the method using both synthetic data and retinotopy data from the Human Connectome Project (HCP). For the synthetic data, the proposed method generated topological and smooth retinotopic maps with higher accuracy than existing methods. For the HCP data, in which ~20% of the visual area is not topological, the proposed method completely fixed the topology violations without reducing the amount of variance accounted for in the fMRI time series. The method also allowed us to generate accurate and automatic boundary delineation, quantify angle distortions between the retina and visual cortex, and improve the measurement of cortical magnification factors (CMF) on the smoothed results. We found that angle distortion from the visual field to the cortical surface was less than 20° for a large part of V1, and the distortion was not symmetric along polar angle for the same eccentricity. Similarly, the CMF is also asymmetric along polar angle. Topological smoothing of retinotopic maps will enable many additional RM quantification.

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3:15 pm

Isolate or combine: population receptive field size in (un)crowding

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Crowding, the deterioration of object recognition in clutter, is traditionally explained with models that are hierarchical, feedforward and local. These models suggest that a “bottleneck” at the earliest stages of visual processing leads to an irretrievable loss of information due to the pooling of target and flanker features, perhaps because of their combination within a single receptive field. A recent study used fMRI and population receptive field (pRF) mapping to estimate aggregate receptive field sizes in early visual areas under conditions of crowding (He et al., 2019). In area V2, pRF size was larger in a stronger crowding condition as compared to an easier one, suggesting that pRF sizes indicate the strength of the “bottleneck”. Here, we tested this assumption by using uncrowding, in which adding more flankers can lead to better performance. In accordance with local, feedforward models, pRF sizes in uncrowding should be the same or larger than in crowding. We estimated pRF sizes in three conditions: crowding, uncrowding and no crowding. We replicated previous results, showing that pRF size was increased in the crowding condition as compared to the no crowding condition. This was the case across visual areas V1 to V4. However, in the uncrowding condition, pRF size was significantly decreased, even compared to the no crowding condition. Again, this was true across all visual areas tested. Our findings not only show that there is “isolation” of the target from the flankers in the uncrowding condition – which may explain the higher task performance, but also provide evidence against purely feedforward models of crowding, including the “bottleneck” theory. We suggest that pRF size is modulated in a recurrent fashion, dependent on global context.

3:30 pm

Feature representation under crowding in V1 and V4 neuronal populations

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Visual features are encoded in a distributed manner spanning numerous cortical areas, with transformations in neuronal selectivity and cortical representation occurring along the visual hierarchy. To understand this distributed sensory code and how it underlies perception, we must identify how feature representations generalize across changes in the environment. Visual crowding, whereby judgments of target features are impaired by adjacent distractor stimuli, provides a powerful paradigm to address these questions, as it involves a range of spatial scales of integration and thus places profound constraints on the relationship between neuronal representations and perception. We asked how crowding by distractor gratings altered the representation of target grating orientation, in simultaneously recorded neuronal populations in V1 and V4 of two fixating macaques. Using a linear population decoding approach, we found that crowding resulted in marked impairments in target orientation discriminability in both cortical areas. Information losses under crowding were more pronounced in V4 populations and varied over a larger range of spatial scales than in V1. Information loss occurred because distractors modulated neuronal responsivity and variability, with both response suppression and facilitation under crowding limiting feature encoding. While both cortical areas exhibited diversity in modulation, the responsivity of V4 neurons was more often facilitated by distractors, in part due to their larger spatial receptive fields. In addition, V4 tuning for targets was altered more strongly by distractors than V1 tuning was. Small changes in the orientation or location of distractor stimuli could strongly perturb tuning in V4, evident both in individual neurons and in neuronal populations. These results reveal that crowding alters the V1 representation of target stimuli, and that these effects are compounded in V4, through greater spatial integration and configuration-dependent tuning. Together these limits on feature discriminability closely approximate those seen in human perception as measured using similar displays.

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3:45 pm

Unraveling brain interactions in vision: the example of crowding

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In visual crowding, the presence of neighboring elements impedes the perception of a target. Crowding is traditionally explained with feedforward, local models. However, increasing the number of neighboring elements can decrease crowding, i.e., lead to uncrowding, which demonstrates the inadequacy of the classic feedforward explanation. Global models are needed, but behavioral experiments alone cannot discriminate between them. Here, we used fMRI to study the effects of (un)crowding on the BOLD response and effective connectivity between visual regions V1 to V4 and the lateral occipital complex (LOC). We tested three experimental conditions: crowding, uncrowding, and no crowding. First, following the standard approach of fMRI crowding studies, we extracted the percent BOLD signal change (PSC) for each condition in each area. We replicated previous results of BOLD attenuation in crowding, beginning in V2 and persisting up the visual hierarchy. However, uncrowding further attenuated the BOLD response, which suggests that PSC is not (monotonically) related to the level of crowding, as commonly assumed. We then used dynamic causal modeling (DCM) and Bayesian model comparison. Specifically, we contrasted top-down, bottom-up and recurrent models. Recurrent models fit the data best in all three experimental conditions, even the simplest no crowding condition. Our results explain the discrepancies between previous fMRI investigations of crowding: in a recurrent visual hierarchy, the crowding effect can theoretically be detected at any stage. Beyond crowding, we demonstrate the need for data-driven models like DCM to understand the complex recurrent processing which presumably underlies perception in general. The DCM framework allows us not only to compare model architectures but also to estimate the computational details of the model in the form of the connection strengths between regions, which can then be used to inform theoretical models.

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Talk Sessions >

Development

Saturday, May 22, 2:30 - 4:00 pm EDT, Talk Room 2 Join Zoom Webinar

Moderator: Mike Arcaro, University of Pennsylvania

2:30 pm

Visual cortex stability and plasticity in the absence of functional cones in achromatopsia

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Purpose: Complete achromatopsia (ACHM) is a rare inherited disorder with non-functional retinal cone photoreceptors and a deafferented foveal representation in V1. Here we investigated whether remapping of the deafferented foveal representation to process paracentral inputs [1] is a group feature in ACHM. Such remapping might interfere with gene therapeutic treatments aimed at restoring cone function. Methods: In a multi-center study we applied fMRI assessments in a cohort of 18 ACHM individuals with confirmed biallelic CNGA3 or CNGB3 mutations and a control cohort (HC). Two independent mapping approaches, conventional phase-encoded eccentricity mapping and population receptive field (pRF) mapping, were applied for both scotopic and photopic stimulation conditions. fMRI-based measures (percentage of active V1, eccentricity, pRF size) were extracted from two anatomically defined V1 regions of interest (ROI), one ROI corresponding to the central visual field (0°-4°) and one ROI corresponding to the paracentral visual field (4°-8°). Two-way ANOVAs with the factors ROI and GROUP (ACHM vs HC) were conducted, comparing scotopic HC data to photopic ACHM data. We hypothesized that remapping associated with the lack of foveal input to V1 in ACHM would lead to a significant interaction of ROIxGROUP. Results: While there were significant effects of the factors ROI and GROUP, no significant interactions (ROIxGROUP) were observed for percentage active voxels ($p = 0.7$), mean pRF eccentricity ($p = 0.3$), or mean pRF size ($p = 0.6$). The results were supported by phase-encoded retinotopic data. Conclusion: Sizeable remapping of the primary visual cortex is not apparent at the group level. We suggest that while functional reorganisation of the primary visual cortex might be evident in specific individuals, it is not a general feature in ACHM.

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2:45 pm

Prediction of retinotopic organization in infant visual cortex from movies

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Mapping the organization of the visual system has enabled considerable progress in understanding different stages of visual processing. This mapping is typically achieved with fMRI-based retinotopy, which requires large amounts of data and central fixation. This can be problematic in populations such as infants, who cannot be instructed to fixate and who tend to produce only ~5 minutes of usable data per fMRI session. We were recently able to perform retinotopy in infants 5–23 months by modifying standard paradigms to reduce the impact of eye movements. However, this was still quite time-consuming, making it difficult to collect enough data in every participant or to perform additional experiments testing

the response properties of the regions of interest identified through retinotopy. Here, we evaluate the feasibility of using movie fMRI data (collected for other purposes in a subset of sessions) to predict the retinotopic organization of infant visual cortex, eliminating the need for a separate retinotopy paradigm. We utilized two approaches with different strengths. First, independent components analysis (ICA) was used to extract components of the movie data that reflect visual evoked signal. With reference to the ground truth from these infants (obtained using retinotopy), ICA discovered eccentricity (foveal-peripheral) maps but rarely found phase (areal boundary) maps. Second, shared response modeling (SRM) was used to transform retinotopic maps between participants using functional alignment. SRM accurately predicted phase maps, but performed worse on eccentricity maps. By combining ICA and SRM, it may be possible to predict the retinotopic organization of infant visual cortex using as little as three minutes of movie data. Beyond the practical uses of obtaining retinotopic maps without specialized tasks, this work also shows the potential of functional alignment with infants and reveals that infant brain activity during passive movie viewing recapitulates the organization of the visual system.

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3:00 pm

A model of the development of major white matter pathways within and between ventral and dorsal visual streams

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The ventral and dorsal visual streams process visual information for different purposes though it is clear that these two streams interact. Recent evidence shows that several white matter tracts directly connect regions associated with ventral and dorsal visual streams. Together, these white matter tracts constitute the posterior vertical pathway (PVP). As of today, we know little about PVP development and even less about its development in relation to ventral and dorsal streams. We propose a model that posits that the development of PVP white matter is related to the flow of neural activity from the ventral visual stream and to the dorsal visual stream. We characterized the development of PVP tracts in a cross-sectional sample of 31 children (4.5-8.5 years old) and 13 adults (18-22 years old) using diffusion-MRI and ensemble tractography. We measured fractional anisotropy (FA) in dorsal (i.e., SLF1and2 and SLF3) and ventral (i.e., ILF, IFOF) streams as well as the four vertical white matter tracts that constitute the PVP (i.e., TPC, pArc, MdLF-SPL, MdLF-Ang). We found that PVP microstructure was more adult-like than the microstructure of the dorsal stream tracts, suggesting that PVP white matter develops earlier than dorsal stream white matter. PVP microstructure was more similar to the microstructure of the ventral than the dorsal stream, suggesting that PVP development follows ventral stream development more closely than it follows dorsal stream development. Finally, PVP microstructure was predicted by performance on a perceptual task in children, suggesting that PVP development is related to developing visual perceptual skills. Overall, results support our model of white matter development and suggest a key role for the PVP in the development of the dorsal visual stream that may be related to its ability to facilitate interactions between ventral and dorsal streams during visual perception.

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3:15 pm

Repetition suppression to visual stimuli following pediatric occipitotemporal cortical resection

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Despite the critical role of occipitotemporal cortex (OTC) in visual recognition, children undergoing cortical resection of OTC show remarkably intact post-operative visual recognition behaviors. In fact, the profile of neural selectivity for visual categories has been shown to be comparable in pediatric OTC resection patients and healthy age-matched controls. This suggests potential underlying neuroplasticity, but it remains unclear whether the integrity of neural representations within a category-selective region is fully intact following resection. With functional magnetic resonance imaging (fMRI), the hemodynamic response is typically suppressed upon repeated presentation of the same stimulus exemplar, a phenomenon termed repetition suppression (RS). RS can thus be used as an inferential measure of the neural computations underlying stimulus individuation. If pediatric OTC resection patients were to evince typical RS patterns in preserved cortex, this would support the claim of post-operative plasticity of higher-level vision. To test this, pediatric patients post-surgery, which did or did not include OTC, and healthy age-matched controls participated in an fMRI study. In the adaptation/RS paradigm, in separate functional runs, participants viewed blocks of either the same visual exemplar presented 12 times (“same” condition) or 12 unique exemplars (“different” condition), each for faces, objects, and words (and an intermediate condition as well). In addition, participants completed an independent functional localizer study to define regions of interest (ROI) for face-, object-, and word-selectivity. RS was approximated as the difference in the average beta weight for the different and same conditions, within each ROI as well as in whole-brain analysis. Across stimulus categories and ROIs, patients (OTC and non-OTC) exhibited RS profiles within the control distribution (confirmed with Crawford statistics for neuropsychological single-subject case studies). These findings suggest that post-resection, residual cortex can fulfill the necessary computations for visual exemplar individuation, potentially explaining the patients’ post-operative behavioral compensations.

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3:30 pm

The developmental trajectory of object recognition robustness: comparing children, adults, and CNNs

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Core object recognition refers to the ability to rapidly recognize objects in natural scenes across identity-preserving transformations, such as variation in perspective, size or lighting. In laboratory object recognition tasks using 2D images, adults and Convolutional Neural Networks (CNNs) perform close to ceiling. However, while current CNNs perform poorly on distorted images, adults' performance is robust against a wide range of distortions. It remains an open question whether this robustness is the result of superior information representation and processing in the human brain, or due to extensive experience (training) with distorted visual input during childhood. In case of the latter, we would expect robustness to be low in early childhood and increase with age. Here we investigated the developmental trajectory of core object recognition robustness. We first evaluated children's and adults' object classification performance on undistorted images and then systematically tested how recognition accuracy degrades when images are distorted by salt-and-pepper noise, eidolons, or texture-shape conflicts. Based on 22,000 psychophysical trials collected in children aged 4–15 years, our results show that: First, while overall performance improves with age, already the youngest children showed remarkable robustness and outperformed standard CNNs on moderately distorted images. Second, weaker overall performance in younger children is due to weak performance on a small subset of image categories, not reduced performance across all categories. Third, when recognizing objects, children—like adults but unlike standard CNNs—heavily rely on shape but not on texture cues. Our results suggest that robustness emerges early in the developmental trajectory of human object recognition and is already in place by the age of four. The robustness gap between humans and standard CNNs thus cannot be explained by a mere accumulation of experience with distorted visual input, and is more likely explained by a difference in visual information representation and processing.

3:45 pm

Developing topographic visual domain organization in a recurrent neural network with biological constraints

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We present a novel account of the origin of domain-selective regions in ventral temporal cortex. We use a deep convolutional neural network model of early visual cortex as input to a multi-layer recurrent map-like model of ventral temporal cortex, and train this model to jointly recognize faces, objects, and scenes. We implement spatially-restricted receptive fields within and between VTC map layers, and restrict feedforward connectivity to be excitatory. Learning in

the model results in the development of smooth topographic domain-selectivity for faces, objects, and scenes, especially in more “anterior” layers of the network. We confirm the functional significance of domain-selectivity using searchlight and lesion analyses. By contrast, the network does not develop topographic domain representations without the excitatory restriction on feedforward connectivity. Further, we implement a more biologically detailed version of the model in which neurons can be only excitatory (E) or inhibitory (I) in their influence on other neurons (Dale’s Law), with only E units projecting feedforward connections. Using two overlaid maps of E and I neurons per VTC area, we again find topographic domain organization in VTC layers. Moreover, E and I units develop column-like responses with overlaid selectivity profiles. In contrast to classical self-organizing map models, we find that spatially broader inhibition is not needed to explain topographic organization. Rather, broadening inhibition relative to excitation gives rise to finer-grained patterning of multiple domain-selective regions whose spatial profiles can be further tuned by the receptive field size. Finally, whereas previous work has simulated topography by explicitly encouraging an exponential decay of pairwise unit response correlation as a function of unit distance (Lee et. al, 2020), this result emerges naturally from learning in our model. In sum, we show that biological constraints on network connectivity can produce topographic domain-selectivity in a distributed neural network without innate domain-specificity.

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Attention, Search, Memory, Crowding

Saturday, May 22, 8:00 - 10:00 pm EDT, Talk Room 1 **Join Zoom Webinar**

Moderator: Chia-huei Tseng, Tohoku University

8:00 pm

Value-driven efficient search is accompanied by differential visual processing area for high- vs low-value objects

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Efficient search (small search slope) is often attributed to pop-out effects that result from low-level visual features. In contrast, we have recently shown that with adequate reward training, non-human primates efficiently search for a high-value target among low-value distractors (target-present trials) regardless of basic low-level features (Ghazizadeh et al. 2016). However, the mechanism of value driven efficient search is not known. In this study, we try to address this issue in the context of a simultaneous decision-making problem. In particular, we utilize a multi-alternative drift-diffusion (MADD) model with various parameters to model decision noise, attention and decision threshold to fit search times in both value-driven target present and target absent trials. To this end, behavioral data of four macaque monkeys trained with a large number of (>300) random fractals which were arbitrarily associated with small or large rewards (i.e., "bad" or "good" objects, respectively) for varying training durations (1-day, 5-days and 30 days) were analyzed. We applied dynamic programming to fit several parametrization schemes of MADD to the data and assessed its performance using cross validation. Preliminary results indicate that longer reward training increases visual processing area differentially for good vs bad objects without significant changes in decision noise or decision threshold. Consistent with this, longer reward training increased the percentage of long-range saccades toward the good objects. Also consistently, the reduction of search slope is only observed for target-present but not target absent trials (search asymmetry). These effects expose a rich, dynamic interaction between reward history and decision making during visual search that is not necessarily explained by classical low-level guiding features. These results suggest that long-term value training may have modified the spatial extent neurons' receptive field in the ventral stream with larger effects for more valuable objects, a speculation that remains to be tested in the future.

8:15 pm

Can attention impair temporal resolution? A spatiotemporal confusion account of temporal impairment following a brief cue

Louisa A. Talipski[1] louisa.talipski@anu.edu.au, Stephanie C. Goodhew[1], Mark Edwards[1]; [1]The Australian National University

Attention is known to enhance many aspects of visual perception. In contrast, however, some authors have claimed that attention elicited by an exogenous cue harms temporal resolution (i.e., the ability to perceive variation in luminance across time). In this study, we examined the possibility that this temporal impairment is not a consequence of attention, but of “spatiotemporal confusion”: participants mistaking the temporal signal provided by the cue’s onset and/or offset for that generated by the target, a possibility that is especially likely when the cue and target are temporally and spatially proximal. We used four attentional cues that differed in their spatial proximity to the target—small and large peripherally presented frames, and centrally presented arrow and gaze cues—and examined the effects of cueing on temporal gap-detection performance, a task which requires participants to distinguish between a single versus a double abrupt luminance change across time. The two peripheral cues flashed on and off prior to target onset, while the two central cues remained on the display until response. Results from a simple reaction-time detection task revealed that all four cues were capable of shifting attention. However, only the two peripheral cues—that is, the cues that were most spatially proximal to the target—generated a temporal impairment on the temporal gap-detection task. When the peripheral cues remained on the screen until response—and therefore spatiotemporal confusion was minimized through eliminating the

luminance change associated with cue offset—no effect of cueing on the temporal gap-detection task was observed, even though the evidence indicated that these cues still produced an attentional shift. These results provide strong evidence that the temporal impairment is not attentional in origin, which, in turn, fundamentally challenges models of attention that claim differential effects of cueing on spatial and temporal resolution.

8:30 pm

Duration compression in unrecognizable objects due to crowding as seen in general shape recognition

Sofia Lavrenteva[1], Ikuya Murakami[1]; [1]The University of Tokyo

Crowded letters subjectively last shorter than non-crowded ones (Lavrenteva & Murakami, VSS2020), but the characteristics and possible mechanisms of this phenomenon are yet to be clarified. To examine whether it is specific to letters, we replicated the phenomenon using non-letter vernier acuity stimuli (two horizontally offset vertical lines) as targets. They were presented on a gray background in the periphery of the right visual hemifield and surrounded by horizontally arranged flankers (digital number ‘8’), five to the left and five to the right of the target. In “crowded” stimuli, the nearest flankers shared its color with the target (e.g., white), while all the other flankers had a different color (e.g., black). In “non-crowded” stimuli, only the outermost flankers had the same color as the target. Similar to the letter targets, the non-letter targets subjectively lasted shorter in the “crowded” stimuli than in the “non-crowded” ones. This implies that duration compression depends not on letter identification, but rather on the occurrence of crowding seen in general shape recognition. In another experiment focused on onset/offset timing error as a potential cause, we used similar stimuli but with digital letters as targets. A clock with a constantly rotating hand was presented in the middle to measure the perceived onset and offset of the crowded and non-crowded stimuli. The offset (but not the onset) of the crowded stimuli appeared to lag behind the offset of the non-crowded stimuli. If anything, this contradicts the duration compression of the crowded stimuli. These results are more consistent with a change of pacemaker rate in the pacemaker-accumulator model of time perception, such that the non-crowded stimuli speed the pacemaker up and/or the crowded stimuli slow it down. This study indicates that processing in “what” pathway of the visual system can distort time perception by affecting the internal pacemaker.

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8:45 pm

Higher-order statistics contained in natural scenes allow task-irrelevant visual perceptual learning of supra-threshold orientation to occur

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Visual perceptual learning (VPL) of orientation occurred as a result of exposure to task-irrelevant supra-threshold natural stimuli (NS), but not to artificial stimuli (AS) that consisted of the identical primitive statistics such as the luminance, orientation, and spatial frequency distributions to those of the NS (Shibata et al., VSS, 2020). Here we examined what factor in NS allows task-irrelevant VPL to occur. Given that the above-mentioned primitive statistics information in AS that was extracted from NS was not sufficient for task-irrelevant VPL, one possibility is that information about spatially regular patterns in NS, which cannot be synthesized by the primitive statistics, is necessary for task-irrelevant VPL. To test this possibility, we used Portilla & Simoncelli stimuli (PSS), which include correlational structures among signals from different positions, orientations, and scales and have the spatially regular pattern information of NS (Portilla & Simoncelli, Int J Comput Vis, 2000). For 10 days, three different groups of participants (n=12 for each) were repeatedly exposed to a set of supra-threshold NS, PSS, or AS with a dominant orientation (trained orientation) while performing a rapid serial visual presentation (RSVP) task. Before and after the exposure, orientation discrimination performance was measured on both the trained and untrained orthogonal orientations. For the trained orientation, significant performance improvement was found in the PSS condition, although it was not as great as in the NS condition. However, no significant improvement was obtained in the AS condition. For the untrained orientation, none of the conditions showed significant improvement. We also found that performance on the RSVP task was significantly lower in the NS and PSS conditions than in the AS condition. These results suggest that the higher-order statistics in the PSS are not suppressed

even if the stimuli are task-irrelevant and partially contribute to VPL of the orientation in the stimuli.

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9:00 pm

Role of memory in a Bayesian ideal observer model of visual search in natural images

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Given a model of target detectability over eccentricity across the visual field, the choice of next fixation is well predicted via a Bayesian ideal observer when the background is 1/f noise (Najemnik & Geisler, 2005). We have recently extended this work to real-world object targets embedded in natural image backgrounds (Rashidi, Ehinger, Turpin, & Kulik, 2020). The presented work studies whether adding short-term memory to the ideal observer model improves predictions of fixation patterns. We recorded eye movements from 5 observers searching for a person in 18 natural backgrounds. The target subtended 0.96 degrees visual angle and could appear at any of 84 possible locations (0-6.75 degrees eccentricity). We model the target detectability against each background using features extracted from deep convolutional neural networks, pooled over spatial regions increasing in size with eccentricity. We feed the calculated detectability maps to the ideal observer model and predict the fixation locations of the human observers. The model assumes that observers integrate information about target location over all previous fixations, so we represent memory span by limiting the integration to the most recent m fixations. We test m=2,4,6,8,10 and perfect memory. We find that the model with a memory span of 4 fixations best predicts human visual search performance (RMSE = 3.476). This improves on the original model which assumes no memory limitations (RMSE = 4.057, $t(17) = 2.921$, $p = 0.0509$). When considering only the backgrounds where the mean number of search fixations is greater than 4, RMSE reduces from 4.879 to 4.07 ($t(11) = 2.214$, $p = 0.0488$). This suggests that the visual system does not take the entire search history into account when selecting the next fixation location, as suggested in the Najemnik & Geisler model. Instead, the choice of next fixation is primarily based on the previous few fixations.

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9:15 pm

The object as the unit of interaction between visual working memory and visual attention

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The current study aimed to answer a fundamental question regarding two central components of our cognitive system: what is the unit of the interaction between visual working memory (VWM) and visual attention. To address this crucial issue, we proposed two opposing hypotheses: (a) the unit of interaction is a Boolean map, which is a data format that can contain only one within-dimension feature (e.g., “red” or “circle”; Boolean-map-unit hypothesis); and (b) the unit of interaction is an object (object-unit hypothesis). We tested these two distinct hypotheses by adopting the memory-driven attentional capture effect as well as manipulating the perceptual organization (objecthood) of two memorized color representations. In two experiments, participants held two colors in VWM from either one or two objects, or one color, and then performed a search task that sometimes contained a singleton-distractor with a memory-matching color. Experiment 1 assessed whether attentional capture would be influenced by the objecthood of multiple representations in VWM. The results showed that two colors in VWM could simultaneously guide attention when encoded from an integrated object, but did not when they came from two separate objects. Experiment 2 replicated the results of Experiment 1 and generalized to two different colors with essentially similar physical formats (i.e., e.g., two different colored semicircles). More importantly, the results showed that the attentional capture by two different colors encoded from one integrated object was equivalent to that of a single color. These results suggested that the objecthood of multiple VWM representations significantly influences their ability for attentional guidance, thus supporting the object-unit hypothesis. These novel findings provided first evidence indicating that the interaction between VWM and attention was implemented at the level of object and have crucial implications for understanding the architecture of interaction between VWM and attention.

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9:30 pm

Spatial extent of audiovisual cross-modal attention

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[Introduction] Effect of the audiovisual cross-modal attention, e.g., facilitation of auditory processing at the location attended visually, has been reported. To understand the underlying mechanism of such audiovisual attention, we estimated the spatial distribution of attentional modulation for visual and auditory processing around the focus of either visual or auditory attentions. [Methods] We measured attentional modulation in visual/auditory processing at 11 stimulus locations along a horizontal line, using a technique with Steady State Responses (SSRs) of electroencephalogram signals. At each of the 11 locations, a letter on a flickering disc was displayed and a loudspeaker was installed for sounds with amplitude modulations for the purpose of SSR measurements. Different temporal frequencies were assigned to the luminance flicker and amplitude modulation at different locations. The SSRs were extracted based on the temporal frequency tagged to each location, based on which we estimated distribution of attentional modulation around the focus of either visual or auditory attentions. Participants paid attention to a location indicated for detecting the target (i.e., A) in sequences of simultaneously presentations of vowel letters and vowel sounds (rapid serial bimodal presentations of A, E, I, O, U) at the location. The letters and sounds were presented also at the other locations to check false responses. [Results] The results showed that visual attention influences auditory responses. Contrary to the prediction, the influence of visual attention on the auditory response was suppression, rather than facilitation, and the influence was found in the area that visual attention covered. The auditory attention, instead, did not show statistically significantly effect on the visual responses, while the SSR amplitude for visual stimuli were larger around the focus of auditory attention than the other locations. [Conclusion] We conclude that there is common attention process with a spatial representation that integrates visual and auditory signals.

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9:45 pm

Saccadic Suppression on Color and Luminance: Evidence from SSVEPs

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Our eyes make saccadic eye movements several times per second to direct the high-resolution fovea toward objects of interest in the environment. During saccades, visual sensitivity is severely suppressed. Currently, there are inconsistent results on whether saccadic suppression occurs in the parvocellular visual pathway in neurophysiological and psychophysical studies. We recorded steady-state visually evoked potentials (SSVEPs) induced by flickering background stimuli (flickering rate = 7.5 Hz) during the execution of saccades (Chen, Valsecchi & Gegenfurtner, 2019, Journal of Neurophysiology). The stimuli were either color-defined (isoluminant) or luminance-defined. Across two experiments, we found reduced SSVEP responses at the time of saccades compared to fixation periods before saccades. More importantly, the reduction in SSVEPs was similar for color-defined and luminance-defined stimuli (Experiment 1: $t(13)=-0.64$, $p=0.53$, $BF_{01}=3.10$; Experiment 2: $t(10)=0.46$, $p=0.66$, $BF_{01}=3.07$). In Experiment 2, we also measured the perceptual performance by asking the observer to discriminate a change of contrast in the stimuli. The change was fixed at a level that gave 82% accuracy during stable fixation measured in a pre-test. At the time of saccades, the accuracy dropped to 78.8% and 69.9% for color-defined and luminance-defined stimuli, respectively. The reduction in perceptual performance was more pronounced for luminance than color, $t(10)=-2.47$, $p=0.03$. Therefore, saccades likely suppress both the magnocellular and parvocellular pathways similarly up to the early visual cortex (see also in Kleiser et al., 2004; Sylvester et al., 2005). Saccades, however, seem to affect their subsequent processes differently, which may give rise to different perceptual suppressions on color and luminance.

Acknowledgements: Natural Science Foundation of China, 31900758

Talk Sessions >

Visual Memory: Working and long-term

Sunday, May 23, 10:30 am - 12:00 pm EDT, Talk Room 1 **Join Zoom Webinar**

Moderator: Niko Busch, University of Muenster

10:30 am

The evolution of complexity in visual memory

Zekun Sun[1] zekun@jhu.edu, Subin Han[1], Chaz Firestone[1]; [1]Johns Hopkins University

Memory rarely replicates exactly what we see; instead, it reconstructs past experiences with distortions and errors. In some cases, memories lose their clarity and detail as time passes; in other cases, however, memories “add” details that weren’t originally there. Though such biases are more commonly associated with naturalistic visual scenes (which may recruit higher-level knowledge or schemas), here we show how memory adds content to even the simplest of stimuli: ordinary geometric shapes. We generated a library of smooth-edged shapes, and manipulated their complexity by gradually simplifying their skeletal structure — essentially altering the “amount of information” in the shapes. On each trial of Experiment 1, subjects saw a novel shape; after a brief delay, a version of the same shape appeared at a different level of complexity, and subjects’ task was to “adjust” the new shape to match the one they had just seen, using a slider that altered the adjustable shape’s complexity. Surprisingly, subjects consistently misremembered the shapes as more complex than they really were (i.e., the shapes they produced had increasingly informationally-dense skeletons). Experiment 2 showed that this finding emerges even at wider ranges of complexity, and Experiment 3 expanded this phenomenon further using the method of serial reproduction. In a “telephone game”, one observer’s recalled shape became the presented shape of the next observer, and so on; these reproduction chains amplified our observed complexity biases, such that 300 observers’ chains converged onto shapes much more complex than had initially been presented. Finally, Experiment 4 ruled out certain forms of strategic responding, finding that the patterns remained no matter the subject’s guess about the effect’s expected direction. These findings reveal a new “complexity bias”, whereby even the most basic units of visual processing are remembered as being more information-dense than they really are.

10:45 am

Fixation-related EEG signatures of memory encoding of real-world scenes

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Although the gist of a scene can be extracted during a single glance, detailed visual memory encoding is suspected to depend on the serial selection of more specific scene information via eye movements. It is yet unknown how aspects of complex real-world scenes are accumulated and stored into memory with each fixation. Exploiting the excellent temporal resolution of the EEG, we investigated how memory representations are enriched with information extracted from successive fixations. We co-registered EEG and eye movements while thirty participants either actively explored the scenes or passively fixated in their center. We then examined oscillations and potentials, both fixation- and stimulus-onset related, as a function of whether a scene was remembered or forgotten in a recognition test 24 hours later. A regression-based deconvolution modeling approach was employed to remove signal distortions from overlapping EEG potentials. In the active viewing condition, we found a subsequent memory effect aligned to the initial presentation of the scene, with a greater positivity at mid-frontal and parietal electrode sites 340-450 ms after image onset for subsequently remembered scenes. Moreover, stronger alpha (7-12 Hz) synchronization was found for fixations on remembered as opposed to forgotten scenes, corroborating the role of an online short-term memory mechanism supporting the maintenance of information within a scene. Lastly, in the low-beta band (15-20 Hz), we found a transition from relatively more synchronization to relatively more desynchronization from the first to the fourth fixation on the scene, suggesting that successive ordinal fixations enrich long-term memory representations for the entire scene. Thus, our results show how the content of memory is updated with each successive fixation. They also emphasize the role of visual short-term memory for the construction of robust long-term memory representations during visual exploration.

11:00 am

Individual differences in the use of motor and visual cues in memory retrieval

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Eye movements during memory encoding act as retrieval cues: evidence shows that memory retrieval is improved when eyes are shifted to the same position where they were located during retrieval. However, it is yet unknown whether it is the motor action or its visual consequence that constitute the retrieval cue associated with eye movements. In this research we examined the visual and motor aspects of eye movements in memory retrieval, and investigated individual differences in the ability to gain from these cues. In our experiment (N=72) we dissociated the visual and motor aspects of eye movements during memory encoding and retrieval. In each trial, participants performed two sequential saccades to the left or right, and then were presented with a target word at the final landing position. The trials varied in vertical location, as the horizontal saccades were performed either at the top or bottom part of the screen. During retrieval, participants performed the same task but they were also asked to indicate whether the target was presented before. Each retrieval trial matched its accompanying encoding trial in: the direction of the saccades (motor-only cue), the vertical location (visual-only cue), both (motor-visual cue) or neither (no cue). Findings revealed that participants varied in their ability to gain from eye movements as retrieval cues: while some participants benefitted from motor and visual cues, others did not. We additionally found that recognition performance in the motor-only condition was positively correlated across participants with performance in the visual-only condition, even after memory capabilities were controlled for. To conclude, these findings suggest that the ability to gain from eye movements as retrieval cue is an individual trait. Individuals who tend to benefit from eye movements as retrieval cues, tend to gain from both aspects of these cues (motor and perceptual) to a similar extent.

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11:15 am

Remembering similar items results in better visual working memory performance due to chunking and not due to more detailed encoding

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Many models of memory predict that similar stimuli will interfere with each other impairing performance in memory tasks. Yet, contrary to this expectation, some data in change detection tasks has found a benefit when the display colors are similar (all green for example) as compared with when they are dissimilar (each a different color category) (Lin & Luck, 2009). We investigated two possible explanations for this effect. First, it could be that when display colors are all within category, subjects are prompted to encode the colors in more specific detail (e.g. 'light green' etc.). As foils are always within category, a more specific encoding in the similar condition would be more likely to result in detection of a change. A second possibility is that when display colors are very similar subjects can use chunking or ensemble encoding strategies, reducing the set size of the display or increasing the information available to support their response. We replicated the original study, and compared performance across different within-category displays that varied in how distinguishable the colors were from each other. Consistent with both hypotheses, the replicated effect was only evident on 'change' trials; participants were more likely to respond 'same' on a change trial in the heterogenous condition. The benefit of similarity varied, however, as a function of how many distractors were close to or indistinguishable from the test item, and dropped off completely as display colors became highly distinguishable. Performance was highest when the foil was the furthest color from the test color, and when the foil was further from the test color than either of the two distractors. These results suggest that the performance benefit is due to chunking of very close or indistinguishable display colors, and the contrast between the foil and gist information of the display colors.

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11:30 am

When participants report zero confidence in their visual working memory, how much information do they really have?

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There is a debate surrounding whether visual working memory is continuous (Ma, Husain & Bays, 2014) or discrete (Zhang & Luck, 2008). The former theory assumes that people maintain some information about all items in a display, whereas the latter proposes that discrete loss of item information can occur. The goal of our study was to determine whether people actually guess in working memory tasks. To address this question, we leveraged confidence ratings and presented 960 intermixed trials of a continuous report task and a same-different discrimination task (0˚ or 90˚ from sample orientation). On each trial, participants were briefly presented with 1, 3, or 6 randomly oriented Gabor patches. Next, they were cued to rate their memory quality for a specific item (scale 0-3), after which they had to complete one of the two orientation tasks. Given that people have quite accurate metacognitive awareness (Rademaker et al., 2012), we anticipated that the zero-confidence condition would provide greater sensitivity to test whether any quantifiable amount of information remained present in working memory. Analyses focused on set size 6, as reports of zero confidence rarely occurred at smaller set sizes. As predicted, discrimination accuracy and memory precision increased as a function of reported confidence. In the same-different task, mean accuracy was 51%, 55%, 67%, and 86% for confidence levels 0 through 3, respectively, and 9/10 participants performed no greater than chance level at confidence level 0 ($p > 0.1$ uncorrected). In the continuous report task, the mean absolute error at confidence level 0 was 44.67˚, which did not reliably differ from an expected value of 45˚ for randomly distributed responses ($p=0.76$). Our findings provide compelling evidence that discrete loss of information from visual working memory can indeed occur, and that reports of zero confidence are commonly accompanied by random guesses.

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11:45 am

“Honey, I shrunk the scene”: Changing perceived distance alters memory for scene boundaries

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Memory for visual scenes is a constructive process that is prone to systematic distortions. These distortions can reveal the mechanisms by which the visual environment is encoded in the mind. One striking distortion is “boundary extension”, whereby observers mistakenly recall viewing a scene from farther away than actually observed—and recent work has revealed the existence of a surprising, complementary effect of “boundary contraction”. What memory processes drive these distortions? We hypothesized that these distortions are driven by normalization toward canonical viewing distances, pushing memory outward for close-up scenes and inward for distant scenes. We directly tested this hypothesis by exploiting image manipulations that selectively alter perceived distance while preserving other perceptual and semantic content. First, we created “fake miniatures” of distant scenes using a digital “tilt-shift” effect, which simulates the shallow depth-of-field of close-up images. For example, we made a distant railway scene appear to be a diorama with a toy train. If memory distortions are dependent on how far away a scene appears, then decreasing perceived distance should increase boundary extension. We embedded distant scenes and “close-up” (tilt-shifted) versions of the very same scenes in a boundary judgment paradigm: Participants reported whether a probe image was closer-up or farther-away than a briefly displayed (250ms) and masked target. As predicted, tilt-shift induced powerful increases in boundary extension at the image-level (Experiment 1)—an effect that could not be explained solely by the manipulation’s low-level properties, e.g., the addition of blur gradients or saturation (Experiment 2). A final experiment showed that the perceived-distance effect generalizes to a completely different image manipulation: a spherical distortion which reduces perspectival cues to distance. Taken together, our results reveal that perceived viewing distance plays a causal role in driving memory distortions for scene boundaries, suggesting that scene memories are biased toward canonical views.

Perception and Action

Sunday, May 23, 10:30 am - 12:00 pm EDT, Talk Room 2 Join Zoom Webinar

Moderator: Cristina Beccio, University of Genoa

10:30 am

Deep learning human action intention classification from natural eye movement patterns

Ali Shafti[1] a.shafti@imperial.ac.uk, Paul Festor[1], Pavel Orlov[1], Mickey Li[1], A. Aldo Faisal[1]; [1]Imperial College London

As human life integrates further with machines, there is a greater need for intuitive human-machine interfaces. Gaze has for long been studied as a window into the human mind, with gaze control interfaces serving to manipulate a variety of systems from computers to drones. Present approaches do not rely on natural gaze cues, however, and use instead concepts such as dwell time or gaze cursors to capture the human command whilst avoiding the problem of Midas Touch. We present a deep learning approach to human object manipulation intention decoding solely based on natural gaze cues. We run data collection experiments with healthy right-handed adults (n=15, 11 males, 4 females), interacting with 6 different objects on a table, when cued with tasks requiring inspection and manipulation. All of them were involved in three-hour sessions with breaks where they were asked to complete visuomotor tasks. In total, around 14,000 individual trials were completed and recorded. This lead to a dataset of human motor and non-motor intentions coupled with high-frequency eye movement data, in the context of a dining table object manipulation scenario. We modelled the task as a time series classification problem and took inspiration from Natural Language Processing sentiment analysis models to design an architecture based on bidirectional LSTMs. Our model was trained and evaluated on our dataset using 5-fold cross-validation. Results show that we can decode human intention of manipulation as opposed to inspection, solely from natural gaze data, with 78.5% average accuracy (1.64% standard deviation). This shows the feasibility of natural gaze interfaces for human-machine interaction, particularly in the context of robotic systems seamlessly supporting their users with object manipulation in different settings, be that assistive for patients with movement impairments, or collaborative, in industrial or service robots.

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10:45 am

Stimulus dependence of theta rhythmic activity in primate V1

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A growing body of psychophysical research suggests that perceptual sampling of complex environments might occur at a theta rhythm (3-8 Hz). Electrophysiological recordings point to a neural origin of this theta-rhythmic sampling mechanism in higher level cortical areas, often associated with exerting top-down attentional influences on perception. Theta oscillations can also be found in extrastriate visual areas when animals see multiple stimuli. However it remains unknown whether theta oscillations can be observed in primary visual cortex (V1) and to what extent their emergence might depend on stimulus properties. To address these questions, we recorded multi-unit activity (MUA) and single unit activity (SUA) from the V1 of two macaque monkeys passively viewing a visual stimulus with variable properties. Analysis of the MUA showed that among the visually responsive electrode sites (n = 107 in Monkey 1 and n = 78 in Monkey 2), more than 50 % showed a statistically significant theta oscillation when the stimulus appeared compared to a baseline period without a stimulus. Doing the same analysis for single units (n = 38 in Monkey 1 and Monkey 2), we found that more than 80 % of the sampled visually responsive units showed a statistically significant theta oscillation. Theta power varied depending on size, contrast, and orientation of the stimulus. Within each of these stimulus property domains (e.g. size), there was usually a single stimulus value that induced the strongest theta. The present study shows that a highly stimulus dependent neuronal theta oscillation can be elicited in V1 at the earliest level of visual cortical processing. In contrast to extrastriate areas, theta can be observed in V1 in the presence of a single stimulus. Stimulus driven theta oscillations in visual cortex might be an additional mechanism for perceptual sampling that occurs at the same frequency range.

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11:00 am

Impairments of visually-guided reach plans after transcranial magnetic stimulation over the human medial posterior parietal cortex

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The medial posterior parietal cortex (mPPC) is involved in the visual guidance of reaching. Although several studies investigated reaching performed towards different directions, only a few correlational studies investigated different depths. Here, we studied the causal role of mPPC (putatively, human area V6A - hV6A) in encoding depth and direction of reaching performed under visual guidance. Fifteen healthy humans performed a visually-guided reaching task which required different eye-hand configurations (foveal and peripheral reaching): Constant gaze configuration (central gaze fixation while reaching to one of 8 peripheral targets); Constant reach configuration (reaching to the central target while fixating one of 8 peripheral targets); Foveal reach configuration (coincident fixation and reaching targets). We applied single-pulse transcranial magnetic stimulation (TMS) over the left hV6A at 100 or 200 ms after reaction time onset, over area V1 to check for non-specific effect of TMS, and in a SHAM condition with the coil tilted 90° over the vertex. We found a site-specific and time-dependent effect: in particular, TMS delivered over hV6A 200ms after the Go signal affected the encoding of the depth of reaching by decreasing the accuracy (in depth) of movements towards targets located farther with respect to the gazed position, but only when they were far from the body (Constant gaze configuration: repeated-measure ANOVA, Stimulation Condition x Stimulation Time x Depth interaction, $F(4,56) = 3.00$; $p = 0.03$, partial $\eta 2 = 0.17$). Reach end-point precision was not affected by TMS over hV6A. The effectiveness of both retinotopic (farther with respect to the gaze) and spatial (far from the body) position is in agreement with the presence in the monkey V6A of neurons employing either retinotopic, spatial, or mixed reference frames during reach plan. This work provides the first causal evidence of the critical role of hV6A in planning visually-guided reaching movements in depth.

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11:15 am

Intention readout primes action categorization

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Variations in movement kinematics convey intention-related information. Human observers are able to exploit this information when explicitly prompted to do so. However, the question remains as to whether they spontaneously use this information to process the actions of other people. The present study was designed to address this question. Participants ($n = 20$) first completed a primed action categorization task. On each trial, they observed either a grasp-to-drink or grasp-to-pour act (prime) followed by a static picture of an agent drinking or pouring (target). The static picture could be congruent (75% of trials) or incongruent (25% of trials) with the intention of the previously observed grasp. Participants were asked to categorize the action displayed in the static picture as fast as possible whilst remaining accurate. This task served to establish whether spontaneous readout of intention information encoded in grasping kinematics facilitates action categorization. Next, participants completed an intention discrimination task wherein they were asked to discriminate the intention of the grasping acts used as primes in the action categorization task. Using a logistic regression fitted to intention discrimination data for each participant, we determined how intention-related

information encoded in grasping kinematics is read out with single-trial resolution. Analysis of response times in the primed action categorization task showed that categorization responses were facilitated by congruent kinematic primes (priming effect: 32.4 ± 10.7 ms, mean ± SEM; $t(19) = 3.02$, $p < .01$). Importantly, the amount of facilitation varied with single-trial intention readout, such that kinematic primes that were more informatively read out by participants in the intention discrimination task induced larger priming effects (Pearson correlation between priming effect and amount of intention information readout: $r = 0.13$, $p < .001$). These findings demonstrate that intention-related information encoded in movement kinematics is implicitly readout and spontaneously used to process others' actions.

11:30 am

Stability versus natural hand pose: Humans sacrifice their usual grasp configuration to choose stable grasp locations

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Choosing appropriate grasp points on objects requires considering several factors. We aim to understand grasp preference when we put natural hand configuration in conflict with grasp stability. Twenty-one participants grasped and lifted objects using their right hand's thumb and index finger. We rotated three brass cuboids to be either aligned or unaligned with the individual's natural grasp axis (NGA) to investigate when and how people stray from their natural hand configuration. Grasp stability was manipulated by changing the surface properties on the cuboids: (a) all-brass, (b) two opposing sides covered with thin wooden strips and (c) two opposing brass sides smeared with Vaseline with the remaining two sides covered with sand paper. Analyses of the grasps on the all-brass object revealed the effect of object orientation: Participants grasped the NGA aligned cuboids with both, clockwise and counterclockwise grasps, but the cuboids rotated away from the NGA primarily with clockwise grasps. This behavior avoided extreme joint angles at the moment of the grasp. Grasps on the wood and sand paper objects, however, were significantly attracted toward the higher friction sides: People grasped the wooden sides more often than the brass sides and the sand paper sides more often that the Vaseline covered brass. The attraction towards the higher friction surfaces was significantly stronger in the sand paper than wood conditions. Our findings show that participants do not tolerate grasp locations on lower friction surfaces to maintain their usual grasp configuration; they instead favor grasps that ensure stability over hand configurations that may minimize energy expenditures. A simple model in which individual participants' NGAs are shifted proportionally to the visually-perceived friction of the cuboid surfaces neatly accounts for our results. These findings suggest a crucial role of surface material properties in grasping.

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11:45 am

Foothold selection during locomotion over rocky terrain

Karl Muller[1] karl.muller@utexas.edu, Jonathan Matthis[2], Mary Hayhoe[1]; [1]University of Texas at Austin, [2]Northeastern University

Very little is known about how visual information is used to guide foot placement during natural locomotion. Previous work studying the role of vision in locomotion has largely relied on constrained environments like treadmills or visual stimuli presented to head-fixed subjects. While these types of experimental controls are helpful for understanding such a complex behavior, there is also much to be learned from studying the behavior as it unfolds naturally. Using an apparatus that combines mobile eye tracking (Pupil Labs), IMU based motion capture (Motion Shadow), and photogrammetric software (Meshroom), we collected a novel dataset that features measurements of gaze direction, body position, and 3D environmental structure as subjects navigate across various outdoor terrains. The dataset is spatially and temporally aligned, so that the gaze direction, body position, and environmental structure information is all in the same coordinate frame, represented as a triangle mesh or a point cloud. Use of Meshroom on the Pupil Labs scene camera images allows correction for IMU drift by fixing the scene relative to the head. The median distance between foothold estimates across 12 different walks and subjects is 3cm. This is much more accurate than previous estimates which assumed a flat ground plane. Using this method, we have examined the distribution of terrain smoothness at locations where subjects fixated, and placed their feet. Differences in smoothness statistics between foothold locations and comparable control locations are modest. However, a convolutional neural network (CNN) trained to distinguish an actual from pseudo randomly selected foothold locations can do so at 65% accuracy. This suggests that there are indeed visual features that differentiate suitable from unsuitable footholds, but the differences are small. Since we found high replicability between paths chosen for different walks and different subjects, a stronger determinant of where subjects walk may be path feasibility.

Acknowledgements: NIH grants EY05729 and EY028229

Motion Perception

Sunday, May 23, 12:30 - 2:00 pm EDT, Talk Room 1 **Join Zoom Webinar**

Moderator: Laurence Harris, York University

12:30 pm

Self-motion cues in the natural habitats of zebrafish support lower visual field bias

Emma Alexander[1], Venkatesh Krishna S.[2], Tim C. Hladnik[3], Nicholas C. Guilbeault[2], Lanya T. Cai[1], Tod R. Thiele[2], Aristides B. Arrenberg[3], Emily A. Cooper[1,4]; [1]School of Optometry & Vision Science Program, University of California, Berkeley, [2]Department of Biological Sciences, University of Toronto, [3]Werner Reichardt Centre for Integrative Neuroscience, Institute of Neurobiology, University of Tübingen, [4]Helen Wills Neuroscience Institute, University of California, Berkeley

The optomotor response (OMR) behavior in larval zebrafish comprises swimming prompted by visual motion cues. This behavior is likely key to self-stabilization in moving aquatic environments. Larval zebrafish collect visual information from a very large field of view (>120 degrees both horizontally and vertically), but they preferentially respond to motion in the lower and posterior visual field with OMR (Wang et al., Cell Reports, 2020). We hypothesized that this preference reflects an adaptation to gather sensory signals from regions in the visual field where optical flow is most reliably informative about self-motion. To test this hypothesis, a video dataset was collected in nine natural shallow-water habitats located across the ecological range of the species. The videos were recorded using a 360-degree underwater camera, attached to a robotic gantry that moved through a series of controlled trajectories, including rotations and translations at multiple speeds. The total dataset includes several minutes of data for each trajectory, collected at 100 frames per second. Using an optical flow analysis on this dataset, we mapped the spatial distribution of several metrics of motion cue quality. We show that the lower visual field contains more texture information, produces more accurate motion cues over the dataset, and provides lower variance estimates of image motion from frame to frame. These factors likely contribute to more accurate and reliable self-motion estimates from the lower visual field compared to the upper visual field. The motion statistics found in our dataset both explain the lower-field bias seen in zebrafish OMR behavior and suggest practical design strategies for visual guidance systems in underwater robotics applications.

12:45 pm

Non-rigid motion perception from optic flow

Krischan Koerfer[1] krischan.koerfer@uni-muenster.de, Markus Lappe[1]; [1]University of Muenster

Perception of non-rigid motion of water, clouds, fire, bird flocks etc. is challenging. Their optic flow patterns deform over time, lack clear borders, have independently moving parts, and can even be inconsistent with their motion. We investigated whether non-rigid motion can be perceived via the dynamics it causes in the optic flow. We developed three types of rotating pattern stimuli that contain different flow properties. Each single frame of a stimulus consisted of a random dot distribution devoid of any structural information. Across frames, the dots were rotated around the center of the pattern. The speed of the rotation depended on the distance to the center. In the first pattern, dot speed increased with distance up to a maximum, while dots further away stood still, creating a sharp boundary. In the second pattern, dot speed decreased with distance like in a water vortex. In the third pattern, dot speed was constant throughout the screen. The patterns themselves then moved over the screen. The dots did not follow this motion, only the center of the rotation moved, so this motion was independent from the instantaneous optic flow. Subjects were well able to report the final position and travelled path for all three patterns, showing that perception did not rely on borders or speed differences in the optic flow but on its dynamics. Adding a coherent global motion did not hamper performance, but adding local noise did, indicating that the visual system derives the dynamic pattern on a local scale. In a subsequently speed discrimination experiment, subjects judged the non-rigid patterns only slightly slower than a rigid control stimulus, revealing that speed perception was not just based on the instantaneous optic flow. We propose that the visual system can use the dynamics in the optic flow for motion perception of non-rigid objects.

Acknowledgements: This research was supported by the German Research Foundation project LA952-7

1:00 pm

Body posture affects the perception of visually simulated self-motion

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Perceiving one’s self-motion is a multisensory process involving integrating visual, vestibular and other cues. The perception of self-motion can be elicited by visual cues alone (vection) in a stationary observer. In this case, optic flow information compatible with self-motion may be affected by conflicting vestibular cues signaling that the body is not accelerating. Since vestibular cues are less reliable when lying down (Fernandez & Goldberg, 1976), conflicting vestibular cues might bias the self-motion percept less when lying down than when upright. To test this hypothesis, we immersed 20 participants in a virtual reality hallway environment and presented targets at different distances ahead of them. The targets then disappeared, and participants experienced optic flow simulating constant-acceleration, straight-ahead self-motion. They indicated by a button press when they felt they had reached the position of the previously-viewed target. Participants also performed a task that assessed biases in distance perception. We showed them virtual boxes at different simulated distances. On each trial, they judged if the height of the box was bigger or smaller than a reference ruler held in their hands. Perceived distance can be inferred from biases in perceived size. They performed both tasks sitting upright and lying supine. Participants needed less optic flow (perceived they had travelled further) to perceive they had reached the target’s position when supine than when sitting (by 4.8%, bootstrapped 95% CI=[3.5%;6.4%], determined using Linear Mixed Modelling). Participants also judged objects as larger (compatible with closer) when upright than when supine (by 2.5%, 95% CI=[0.03%;4.6%], as above). The bias in traveled distance thus cannot be reduced to a bias in perceived distance. These results suggest that vestibular cues impact self-motion distance perception, as they do heading judgements (MacNeilage, Banks, DeAngelis & Angelaki, 2010), even when the task could be solved with visual cues alone.

Acknowledgements: We acknowledge the generous support of the Canadian Space Agency (15ILSRA1-York).

1:15 pm

Bimodal probability distributions decoded from human visual cortex reflect perception

Andrey Chetverikov[1] andrey.a.chetverikov@gmail.com, Janneke F.M. Jehee[1]; [1]Donders Institute for Brain, Cognition, and Behavior, Radboud University

How do humans infer an object’s direction of motion from noisy sensory input? We hypothesized that observers utilize not only motion but also orientation information in their inferences, capitalizing on “streaks” created by moving objects (see also Geisler, 1999, Nature). We implemented this hypothesis in an ideal (Bayesian) observer framework, in which an observer’s knowledge is quantified using probability distributions. This led to several predictions that we tested using psychophysics and fMRI. Participants viewed dots moving coherently in a random direction and then reported the perceived direction of motion. Using a probabilistic pattern-based analysis (cf. van Bergen, Ma, Pratte & Jehee, 2015, Nature Neuroscience), we decoded the probability distribution of motion direction from activity patterns in visual areas V1-V4, and hMT+. Corroborating the predictions of the Bayesian observer model, we found that 1) probability distributions decoded from cortical activity had a characteristic bimodal shape, consistent with the notion that orientation might provide an important cue to the direction of motion. 2) The widths and 3) locations of the two peaks of the decoded probability distributions predicted, respectively, trial-by-trial variability in the participants’ behavioral responses, and the magnitude and direction of their behavioral errors. Finally, (4) in a follow-up behavioral experiment, analysis of the behavioral response distribution revealed a similar bimodal pattern, with one peak roughly centered at 0° and the other at 180° with respect to the true motion direction. Thus, observers sometimes perceived the stimulus as if it moved in a direction opposite to its true direction of motion, as predicted by the model. Together, these results suggest that human observers use not only motion, but also orientation information in their judgments of a moving stimulus, and moreover reveal the neural basis of the inference process involved.

Acknowledgements: This work was supported by ERC Starting Grant 677601 to J.F.M.J. A.C. received an Excellence Fellowship from Radboud University.

1:30 pm

Motion silencing explained as an error of interpretation

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Failures of perception often support inferences about processing limitations: bottlenecks, and limited attention, for instance, as revealed by the attentional blink, change blindness and other examples. Motion silencing is a striking illusion that has been interpreted along these lines. The illusion is that observers fail to see individual dots changing color when the dots constitute a larger disc which is rotating as a whole (but not a stationary disc), a failure thought to be caused by too much information to process at once. Using methods that closely follow the original illusion report, we investigated the alternative hypothesis that silencing reflects the erroneous inference that detected color changes were spuriously caused by the rotating motion. We support this hypothesis, first, by demonstrating a situation in which color changes are perceived despite large amounts of motion energy. Specifically, with randomly moving dots inside of a confined space observers perceive color changes as robustly as they do when the dots remain unmoving. If color changes can be perceived in the presence of motion, then motion itself cannot be the limiting factor. Second, we used a pair of controlled stimuli to demonstrate that the illusion obtains only when the visual system has reason to infer an underlying object upon which all the dots are set. Specifically, when two groups of oppositely translating dots were presented, participants saw a three-dimensional rotating cylinder and critically, when the dots changed colors, the silencing illusion obtained. When the two sets of dots translated in the same direction, removing the cylinder percept, silencing was reduced ($p < 0.001$). A limitation caused by motion should be equally present when dots translate in the same or opposite directions. That silencing is only present when an underlying object is implied reveals the illusion as an interpretive error.

1:45 pm

Bayesian interpretation of artificial neural network models in perception

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Bayesian observer models and artificial neural networks (ANNs) in computer vision operate on the same general premise that vision reflects optimal behavior. Thus, a Bayesian interpretation of ANNs could provide intuitive understanding of the networks' computational properties as well as insights into how Bayesian computations can emerge through algorithmic learning. We explored such an interpretation for a recently proposed ANN model of motion perception (Rideaux/Welchman, 2020). The network, trained to identify translational motion categories of natural images, showed similar perceptual biases toward slow speeds as has been observed for human subjects. The authors note, however, that because the distribution of training samples was uniform across all motion categories, these biases cannot be due to a slow-speed prior. We demonstrate that the geometry of the feature space is crucial for making a correct Bayesian interpretation. Although the distribution of training samples was uniform across categories, it did not correspond to a uniform distribution in 2D velocity space because the chosen categories were not equidistant in this space. Similarly, the categorical loss function (cross-entropy) more strongly penalized low-speed errors as the categories were closer at low speeds. Both aspects led to an over-representation of slow-speed motion, thus effectively embedding a slow-speed prior. We show that by correctly accounting for the geometry of the feature space, the ANN estimated speeds are in agreement with predictions from a Bayesian observer model. Furthermore, we show that the amount of sensory uncertainty depends on the architecture of the network (i.e. its resource), e.g., the kernel size of the convolutional layer determines the likelihoods of the motion stimuli. Together, our results show that ANN models of perception can be interpreted as an algorithmic implementation of a Bayesian inference process given resource constraints and the proper combination of prior, likelihood, and loss structure of the task.

Acknowledgements: NSF grant IIS-1912232

Eye movements: Saccades, pursuit, vergence

Sunday, May 23, 12:30 - 2:00 pm EDT, Talk Room 2 Join Zoom Webinar

Moderator: Jolande Fooken, University of British Columbia

12:30 pm

Sports athletes use predictive saccades! But why?

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In sports, high-level athletes are able to predict the actions of an opposing player. Interestingly, such predictions are also reflected by the athlete's gaze behaviour. In cricket, for example, a bowler bowls the ball in the direction of a batsman. The ball first bounces on the ground before the batsman tries to hit the ball with his bat. During the ball flight, players very often initiate two predictive saccades: one to the predicted ball-bounce point and a second to the predicted ball-bat-contact point. That means, they move their eyes ahead of the ball and "wait" for the ball at the new fixation location, potentially using their peripheral vision to update information about the ball's trajectory. In this study, we investigated whether predictive saccades are linked to the processing of information in peripheral vision and if predictive saccades are superior to continuously following the ball with foveal vision using smooth-pursuit eye-movements (SPEMs). In four experiments (Experiments 1a, 1b, 2a, and 2b), we first compared speed-discrimination performance when using foveal vision (during SPEMs) or peripheral vision (during fixations). We found that speed discrimination performance was better during pursuit than during fixation. In the next two experiments (Experiment 3 and 4), we evoked the typical eye-movements observed in cricket. Results show that the information gathered during SPEMs is sufficient to estimate when the target will hit the fixated location, and that peripheral monitoring does not help or is not used to improve this estimation. Finally, in the last experiment (Experiment 6), we show that it may actually be beneficial to use SPEMs to predict the TTC of a moving target rather than predictive saccades. Thus, predictive saccades that move fixation ahead of a target are unlikely to be performed to enhance the ability to peripherally monitor a moving target.

12:45 pm

Ability of the peripheral visual field to maintain motor alignment

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Objective: Some patients are believed to use peripheral vision to achieve motor eye alignment. The objective of this study was to test the ability of peripheral field to drive vergence. Method: 8 adults (15 to 51 years) participated. Naturalistic images (SYNS dataset) were presented dichoptically (80x60deg) with a monocular fixation target and binocular mean luminance simulated central scotoma (radii 0,5,10,15,20, or 25 deg). The scotoma had a smooth transition to the image and antiphase serration in the periphery in two eyes. In each trial, the subjects performed a nonius task to confirm alignment before the image stepped to a disparity (0,0.5,1,2,4, or 8 deg) for 1.5 secs while responses were recorded with an Eyelink1000 (SR-Research). Six repetitions were performed in random order. Results: Disparity tuning with no scotoma was similar to the previous literature, peaking at 1° disparity for divergent & 2° for convergent stimuli. Mean open loop vergence amplitude at the second latency point for 0°, 5°, 10°, 15°, 20° & 25° scotoma were 0.41+/-0.23, 0.42+/-0.18, 0.62+/-0.14, 0.42+/-0.13, 0.21+/-0.11, 0.21+/-0.45 deg when averaged across 2° convergent and divergent disparities. At 0° scotoma, subjects were able to respond to the smallest disparity, but as scotoma size increased (at 20°& 25°), there was minimal response to disparity < 2°. Conclusion: Peripheral visual field (to 40° eccentricity) is able to initiate vergence responses to the removal of a 25° radius central scotoma, with reduction in response amplitude that varies across individuals. The highest amplitude was at 2-deg of disparity for all scotoma sizes. This has implications for understanding how patients with central scotomas resulting from suppression or retinal pathology may be able to maintain eye alignment.

1:00 pm

Asymmetrical movement of the covered eye during midline saccadic/jump vergence while accommodation remains symmetrical.

Arvind Chandna[1,2] arvind@ski.org, Devashish Singh[1], Stephen Heinen[1]; [1]Smith Kettlewell Eye Research Institute, [2]Alder Hey Children's Hospital. Liverpool. U.K.

For midline targets vergence and accommodation between the two eyes are believed to be symmetrical, controlled by unitary commands and both facilitated by cross-links. These are important considerations in strabismus treatment. We have previously demonstrated that for midline smooth pursuit, under monocular viewing, the covered eye does not follow the viewing eye while accommodation remains symmetrical, questioning the unitary vergence command and cross links. The purpose of this study was to see if the saccadic or jump vergence system, shared similar characteristics. Subjects underwent a detailed clinical examination to confirm typical visual and oculomotor characteristics. Subjects were seated at the end of a 6-meter track with their head resting securely on a chin rest. Subjects alternated on command between fixation on a far target (350 cm) to a near target (33 cm) as it flashed in front of them along the midline. Eye movements and accommodation were simultaneously measured with the PlusOptix PowerRefractor. Data was collected from both eyes during binocular viewing and during monocular viewing with the fellow eye occluded with an IR passable filter. During binocular viewing saccadic/jump vergence was synchronous between the two eyes as was accommodation. However, during monocular viewing, the occluded eyes for all subjects showed variable eye movements from desynchronized jump vergence to conjugate saccadic movement while accommodation remained symmetrical between eyes. Comparisons of the linear regression slope of each eye for vergence and accommodation and standard calculation of vergence confirmed these results to be true. Our results suggest that during monocular midline saccadic/jump vergence the covered eye is not under a unitary vergence command and indicates the absence of the putative cross-link where accommodation drives vergence. This is similar to our previous results with monocular pursuit vergence user a similar paradigm suggesting these characteristics are not reserved for one set of eye movements.

1:15 pm

OpenEyeSim 2.0: Simulation of accommodation, depth-of-field, chromatic aberration, and contrast sensitivity in a biomechanical model of the oculomotor system

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We introduce OpenEyeSim 2.0, a detailed model of the biomechanics of human extraocular eye muscles and retinal image formation. Like its predecessor OpenEyeSim, it features realistic muscle paths, muscle pulleys, and muscle dynamics. In addition, OpenEyeSim 2.0 incorporates an efficient approximation of retinal image formation including accommodation control, depth-of-field effects, longitudinal chromatic aberration, and contrast sensitivity. Compared to ray tracing, our rendering process is kept simple and efficient, thereby facilitating studies on human vision development with large numbers of simulation steps. This makes OpenEyeSim 2.0 a versatile platform for developing computational models of the joint learning of visual representations and eye movement and accommodation control in the full perception action cycle. To simulate accommodation control and depth-of-field effects during retinal image formation, we use a simple but computationally efficient lens model. The model simulates different accommodation states (focal point, pupil aperture) by using a custom shader during the rendering process. Different levels of blur are applied pixel-wise based on an object's distance to the focal point and lens parameters. Longitudinal chromatic aberration is thought to play an important role in accommodation control and its development. OpenEyeSim 2.0 efficiently approximates chromatic aberration by an additional custom shader which applies different color manipulations during rendering of the three RGB color channels. As an additional component, OpenEyeSim 2.0 allows the simulation of different contrast sensitivity functions as measured in children from 1 to 8 months of age to study the effects of contrast sensitivity on visual development. To the best of our knowledge, OpenEyeSim 2.0 is the first simulator to combine realistic extra-ocular muscle dynamics with a simplified yet plausible model of retinal image formation including accommodation control, depth-of-field rendering, and chromatic aberration effects.

1:30 pm

Dependence of perceptual saccadic suppression on peri-saccadic image flow properties and luminance contrast polarity

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Perceptual detectability of brief visual stimuli is strongly diminished across saccades. Recent work showed that this perceptual suppression phenomenon is jumpstarted in the retina (Idrees et al., 2020), suggesting that the phenomenon might be significantly more visual in nature than normally acknowledged. Here, we explored the details of visual-visual interactions underlying saccadic suppression, and we did so by comparing suppression strength when saccades were made across a uniform image of constant luminance versus when saccades were made across image patches of different luminance, width, and trans-saccadic luminance polarity. In 6 human subjects, we measured perceptual contrast thresholds for brief peri-saccadic flashes of positive (luminance increments) or negative (luminance decrements) polarity. In different conditions, gaze crossed a luminance edge or stripe before landing on a uniform background like in the control condition. Perceptual thresholds were >6-7 times higher when saccades translated a luminance stripe or edge across the retina than when the movements were made over a completely uniform image patch. Moreover, both background luminance and flash luminance polarity relative to the background strongly modulated peri-saccadic contrast thresholds: dark backgrounds were associated with the strongest suppression, and negative polarity flashes over dark backgrounds caused stronger suppression than positive polarity flashes over the same backgrounds. Most importantly, we repeated the same experiments on all subjects with rapid image translations (simulating saccadic visual flows on the retina) without any real saccades. All of the image dependencies that we observed with real saccades (e.g. suppression with gaze crossing an edge or stripe versus suppression with a uniform background) also occurred. Our results indicate that perceptual saccadic suppression may be fundamentally a visual phenomenon. They also strongly motivate revisiting both the movement-related and visual components of saccadic suppression, and investigating how saccade movement commands may interact with visual-visual interactions in shaping trans-saccadic visual perception.

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1:45 pm

Humans can smoothly pursue but fail to intercept accelerating targets

Philipp Kreyenmeier[1,2] philipp.kreyenmeier@googlemail.com, Luca Kämmer[1], Jolande Fooken[1], Miriam Spering[1,2,3,4]; [1]Department of Ophthalmology & Visual Sciences, University of British Columbia, Vancouver, Canada, [2]Graduate Program of Neuroscience, University of British Columbia, Vancouver, Canada, [3]Djavad Mowafaghian Centre or Brain Health, University of British Columbia, Vancouver, Canada, [4]Institute for Computing, Information, and Cognitive Systems, University of British Columbia, Vancouver, Canada

The ability to accurately judge the acceleration of moving objects is critical to our survival. Whereas the perceptual system is surprisingly insensitive to acceleration, humans can accurately track accelerating targets with smooth pursuit eye movements. When the target is briefly occluded, predictive pursuit scales with target acceleration, indicating that the oculomotor system forms an acceleration-based prediction of target motion. Here we ask whether acceleration is taken into account when manually intercepting accelerating targets. Participants (n=16) viewed a small disk that moved along a horizontal path with one of four constant, linear levels of acceleration (-8,-4,+4,+8 m/s/s). The target was shown for 800 ms before temporary occlusion. Target velocity was always 20°/s at the time of occlusion, allowing us to test whether participants based their interception on the final target velocity before occlusion, or on continuous target acceleration. Participants had to predict the time of target reappearance by manually intercepting it with a quick pointing movement of their right hand. We recorded participants’ eye and 3D-hand position using an EyeLink 1000 eye tracker and a trakSTAR electromagnetic motion tracking system. The correspondence between target acceleration and eye (smooth pursuit acceleration) or hand (interception timing) were assessed using linear regression. Pursuit acceleration closely matched target acceleration (median slope = .83; 95% CI = [.73, 1.27]). In contrast, participants did not take acceleration into account when timing their manual interception (median slope = -.33; 95% CI = [-.46, -.07]), yielding systematic interception errors–too early for decelerating targets and too late for accelerating targets. Our results show that the oculomotor system can rely on continuous sampling of the target motion, yielding a pursuit response sensitive to target acceleration. Yet, humans might be limited in their ability to predict accelerating targets for hand movement control, relying on the final target velocity sample prior to occlusion.

Color, Texture and Material

Monday, May 24, 12:00 - 1:30 pm EDT, Talk Room 1 Join Zoom Webinar

Moderator: Hannah Smithson, University of Oxford

12:00 pm

Modeling the Effects of Longitudinal Chromatic Aberration Using Chromatic Detection Mechanisms

Yesenia Taveras-Cruz[1] taverascruz.y@northeastern.edu, Jingyi He[1], Rhea Eskew, Jr.[1]; [1]Northeastern University

Longitudinal chromatic aberration (LCA) contributes to retinal-image degradation by introducing chromatic blur, which is strongest for short wavelengths of light. By blurring short wavelengths more than longer ones, LCA can cause an external stimulus designed to modulate only one cone type (e.g., (S)hort-wavelength cones) to produce a retinal stimulus that modulates multiple cones instead. We combine a model of LCA (Marimont & Wandell, 1994) with a cardinal model of chromatic detection to account for two results that were obtained with nominally S-cone isolating Gabor patches, constructed using the silent-substitution method (Estévez & Spekreijse, 1982): 1. Observers noted that Gabors appeared colorful (violet/greenish-yellow) at low spatial frequencies (SFs) and achromatic at higher SFs. 2. Forced-choice detection thresholds produced contrast sensitivity functions (CSFs) with two distinct branches: at low SFs the shape matched method-of-adjustment S-cone hue sensitivity curves, but at higher SFs the shape matched forced-choice luminance CSFs. For some observers, a dip in detection sensitivity occurs between these two branches. Calculations of the retinal-images produced by LCA show that our nominally S-cone isolating gratings contained (L)ong and (M)edium- wavelength cone contrasts that increased in magnitude with SF, relative to S-cone contrasts. These retinal-image cone contrasts were used as input to three cardinal, cone-opponent detection mechanisms: YB (S-cones opposed to LM), RG (L-M), and ID ("increment/decrement" or achromatic), using cone contrast weights compiled in Eskew, McLellan, & Giulianini (1999). The YB and ID response curves intersect around 2-3 cycles/degree, aligning with the sensitivity 'dip' in the S-cone detection CSFs. The dip results from a phase-reversal in the retinal-image cone contrasts produced by LCA ("spurious resolution"). We can account for the shapes of the S-cone detection CSFs, and the change in color appearance at threshold, using the calculated chromatic mechanism response curves.

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12:15 pm

Modeling perceptual discrimination of surface color using image chromatic statistics and convolutional neural networks

Takuma Morimoto[1] takuma.morimoto@psy.ox.ac.uk, Samuel Ponting[1], Hannah E. Smithson[1]; [1]Department of Experimental Psychology, University of Oxford

A previous study measured thresholds to discriminate colors of objects under each of three different lighting environments. Discrimination thresholds were similar for matte and glossy objects, but the orientations of the discrimination ellipses were tightly aligned with the chromatic variation of the lighting environment in which the objects were placed (Morimoto & Smithson, 2018). Using two distinct modeling approaches we analyzed the psychophysical data to reveal the potential strategies that humans used to perform the discrimination task. First, we built three hand-crafted models that discriminate objects' colors by comparing specified chromatic statistics: (i) mean chromaticity, (ii) chromaticity of the brightest pixel, and (iii) luminance-weighted-mean chromaticity. In the second approach, we trained convolutional neural networks (CNNs), based on 38,021 images labelled either by physical ground-truth or human responses. Then, thresholds were estimated for all models using the identical staircase procedure that measured human thresholds. The first approach showed that the mean chromaticity and the luminance-weighted-mean-chromaticity models predicted human thresholds generally well, but the brightest-pixel model predicted thresholds better in some matte conditions, indicating that no tested model based on single chromatic statistics can predict thresholds consistently well across conditions. Moreover, the estimated thresholds for these models were generally higher than human thresholds. In contrast, the CNN trained on images with human responses nearly perfectly predicted human thresholds

in all conditions. The CNN trained on physical ground-truth showed much lower thresholds than human thresholds. Visualizing activation maps of the CNN trained on human responses revealed that the CNN primarily looks at shaded regions of the surface that are dominated by diffuse reflections of indirect illumination and thereby provide more reliable information about surface color. Combining hypothesis-based and data-driven approaches revealed an effective strategy to separate lighting and material to reliably discriminate surface color under complex lighting environments, which humans might also use.

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12:30 pm

Spatial frequency dependence of naturalistic texture perception

Justin D. Lieber[1] justinlieber@nyu.edu, J. Anthony Movshon[1]; [1]Center for Neural Science, New York University

Natural images contain information at multiple spatial scales. To extract this information, the visual system parses these images using independent, spatial-frequency selective channels. However, it is not well understood how these channels are recombined to produce a unified visual percept. To illuminate this process, we measured how well human observers discriminate the presence or absence of naturalistic structure in texture images. We used the method of Portilla & Simoncelli (2000) to generate families of texture images, based on a single ancestral image, that span the range from fully naturalistic structure to spectrally matched noise. We then measured how this “naturalness” sensitivity of human observers depended on signals in different spatial frequency bands, using three different experimental manipulations. First, we removed high frequencies using low-pass filtering. Second, we shifted the frequency spectrum by rescaling the images (as if changing viewing distance). Third, we presented images at different eccentricities. The effect of all three manipulations can be explained if sensitivity to image naturalness disproportionately depends on high-frequency information. Analysis of image statistics present in the image sets indeed shows that high-frequency features provide a more reliable naturalness signal than low-frequency features. Different families of texture images showed idiosyncratically different dependences on different frequency bands. To ask how information in different frequency bands combines to support texture discrimination, we have measured naturalness sensitivity with textures made from mixtures of bandpass filtered components. Information in nearby bands (within an octave) combines efficiently, while information in bands spaced further apart is processed more independently. Our results suggest that the perception of natural image structure is most strongly mediated by information at fine spatial scales and in nearby frequency bands.

Acknowledgements: Thanks to the Leon Levy Foundation for financial support.

12:45 pm

Learning to see material from motion by predicting videos

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Despite the impressive achievements of supervised deep neural networks, brains must learn to represent the world without access to ground-truth training data. We propose that perception of distal properties arises instead from unsupervised learning objectives, such as temporal prediction, applied to proximal sensory data. To test this, we rendered 10,000 videos of objects moving with random rotational axis, speed, illumination, and reflectance. We trained a four-layer recurrent “PredNet” network to predict the pixels of the next frame in each video. After training, object shape, material, position, and illumination could be decoded for new videos by taking linear combinations of unit activations. Representations were hierarchical, with scene properties better estimated from deep than shallow layers. Visualising single “neurons” revealed selectivity for distal features: a “shadow unit” in layer 4 responds exclusively to image locations containing the object’s shadow, while a “reflectance edge” unit in layer 3 tracks image edges caused by reflectance changes. Material decoding was higher for moving than static objects, and increased over the first five frames, demonstrating that the model is sensitive to motion features disambiguating reflective from textured surfaces. To test whether these features are similar to those used by humans, we rendered test stimuli depicting reflective objects that were either static, moving, or moving with “reflections” fixed to their surface. All conditions had near-identical static image properties, but motion cues in the latter conditions give rise to glossy vs matte percepts, respectively. Model-predicted gloss agreed with human judgements of the relative glossiness of all stimuli. Our results suggest unsupervised deep learning discovers motion cues to material similar to those represented in human vision, and provides a framework for understanding how brains learn rich scene representations without ground-truth world information.

Acknowledgements: This work was funded by the Alexander von Humboldt Foundation.

1:00 pm

Measuring the human "chromatic diet" and its relation to preference for color distributions across cultures

John Maule[1] j.maule@sussex.ac.uk, Simeon Floyd[2], Alice Skelton[1], Beata Wozniak[1,3], Asifa Majid[4], Jenny Bosten[3], Anna Franklin[1]; [1]Sussex Colour Group, School of Psychology, University of Sussex, UK, [2]Universidad San Francisco de Quito, Ecuador, [3]Sussex Vision Lab, School of Psychology, University of Sussex, UK, [4]Department of Psychology, University of York, UK

Visual preferences for artworks and scenes tend to align with regularities in spatial scene statistics of the natural world (Graham & Field, 2008, Spatial Vision, 21, 149-64). Similarly, preference is highest for color distributions which coincide with the chromatic variation present in natural scenes (Juricevic et al., 2010, Perception, 39, 884-99). These effects have been attributed to the efficiency of neural coding, or "cognitive fluency" (Reber et al., 2004, Pers. Soc. Psychol. Rev. 8, 364-82), such that the tuning of the visual system to the environment drives aesthetic preference. We compared aesthetic responses to color distributions for observers living in different geographical locations, and quantified the differences in the distributions of colors in their local environments. We measured aesthetic preference for Mondrians containing colors distributed along cardinal and oblique axes in the Macleod-Boynton chromaticity diagram for observers living at three locations – Brighton, UK; Quito, Ecuador; and rainforest in Ecuador. The preferences of UK observers replicated Juricevic et al. (2010): Mondrians with colors distributed along the yellow-blue (oblique) axis were most preferred. We found opposite preferences for participants in urban Ecuador (highest for purple-green distributions), while participants living in the Ecuadorian rainforest showed no consistent preferences. Using color-calibrated GoPro cameras, mounted to the heads of participants, we captured random samples of natural scenes typically encountered in the daily routines for people living in each of the three locations. By measuring the response functions of each camera's RGB channels and recording images in RAW format, we reconstructed the MacLeod-Boynton chromatic scene statistics to which participants were exposed – the "chromatic diet". The pattern of aesthetic preference is not straightforwardly predicted from the analysis of the chromatic diet at each location, challenging the notion that aesthetic preference is strongly driven by tuning to natural statistics.

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1:15 pm

The emergence of color categories in a CNN for object recognition

Jelmer de Vries[1] vriesdejelmer@gmail.com, Karl Gegenfurtner[1]; [1]Justus-Liebig Universität Gießen

Color is the prime example of categorical perception, yet it is still unclear why and how color categories emerge. While color categories have a functional role in communication, prelinguistic infants already respond to colors categorically. Here, we address the emergence of color categories as a result of the general interaction with the visual world. Specifically, we asked whether color categories arise in a convolutional neural network (CNN) trained to recognize objects in natural images. Therefore, we replaced the classification layer of a CNN (Resnet-18) trained on ImageNet and evaluated its performance on various color classification tasks. In Experiment 1 we trained the novel output layer to classify colored words sampled from the hue spectrum (HSV). Systematically varying stimulus colors demonstrates that the network not only generalizes similar colors, but also that the borders between classes are largely invariant to the training colors. Relying on the notion that colors from the same category should be easier to generalize than colors from different categories, in Experiment 2, an evolutionary algorithm finds similar border locations. Finally, in Experiment 3, we investigated a potential functional role of the found borders. Manipulating colors and color contrast we find that even in cluttered color stimuli, classification can still rely on the same borders. The fact that a CNN classifying objects in natural images represents color in a categorical manner, highlights that color categorization may emerge naturally with the development of basic visual skills. Considering the relative ease with which one can inspect the activity of individual neurons in a CNN, compared to a biological system, the current findings also open up an exciting research avenue for uncovering how color categories can be based on lower-level signals.

Scene Perception

Monday, May 24, 12:00 - 1:30 pm EDT, Talk Room 2 Join Zoom Webinar

Moderator: Michelle Greene, Bates College

12:00 pm

Orientation perception is based on efficient coding and categorical decoding

Jiang Mao[1] jiangmao@sas.upenn.edu, Alan Stocker[1]; [1]University of Pennsylvania

Perceived stimulus orientations are typically biased away from cardinal orientations. Wei and Stocker (2015) proposed that these biases are the result of a Bayesian inference process constrained by efficient coding, where higher encoding accuracies for cardinal orientations reflect the natural prior of local orientations. Other studies, however, suggested that natural categories for cardinal and oblique orientations also play a role in the perception of orientation (Rosielle & Cooper, 2001; Wakita, 2004; Quinn, 2004). Here, we systematically tested to what degree efficient coding and the notion of category are necessary to provide a quantitatively accurate account of human psychophysical data. Specifically, we tested how well a Bayesian observer model with/without efficient coding and with/without categorical loss can account for the psychophysical orientation estimation data from De Gardelle, Kouider and Sackur (2010). In formulating a categorical loss function, we assumed that the observer considers four natural orientation categories (horizontal, vertical, clockwise and counterclockwise to vertical) relative to a noisy reference. The total loss function then consisted of a weighted combination of a mean squared error loss term and the categorical loss. We find that the model versions without efficient coding cannot explain the direction, magnitude, or the dependency of the estimation bias on sensory noise. The models with efficient coding are all able to predict the repulsive bias. However, the variance pattern predicted by the efficient Bayesian model without categorical loss doesn’t match the data. Only the model version that incorporates both efficient coding and a categorical loss component is able to quantitatively fit the full distribution of orientation estimate in its minute details. In conclusion, we can quantitatively fit the orientation estimation data with a Bayesian observer model that incorporates both efficient coding and a categorical loss function. Both elements are necessary to explain the distortions in orientation perception.

12:15 pm

Revealing the cortical transformations of real-world scenes using dynamic electrode-to-image (DETI) mapping

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Voxelwise encoding models of BOLD signals offer insight into how information in visual scenes is simultaneously represented in visual cortex. However, a complete understanding of how the brain internalizes visual information requires an understanding of the different transformational states of that information over time. Electroencephalography (EEG) has become a popular technique to understand the nature of those states, but suffers from dipole cancellation, thereby precluding a spatially complete signal of scene information. To circumvent that problem, we present the dynamic electrode-to-image (DETI) mapping procedure. The DETI procedure is an encoder-based approach that capitalizes on the state-space geometry of images and visual evoked potentials (VEPs) to map VEP signals to each location within scene images. Specifically, DETI mapping reduces the dimensionality of VEP signals from different electrodes over time and then maps those signals via a log-Gabor encoding model to each pixel within specific images. We applied this method to data gathered in a standard VEP paradigm whereby participants (n = 24) viewed 80 grayscale scene images (19.5 degrees of visual angle) while undergoing 128-channel EEG. DETI mapping revealed an interesting, possibly two-stage, pattern of transformational states that begin with a low spatial frequency (LSF) state (~50 ms), followed by a high spatial frequency (HSF) state (~70 ms to ~140 ms). Starting around 150 ms, the image transformations undergo what appears to be intermittent LSF transformations at ~180 ms and ~260 ms, possibly indicative of recurrent processes.

Further, time-time regression analyses show that local regions within scenes undergo relatively unique spatiotemporal transformations over time, suggesting different temporal stages of local prioritization of scene information. The DETI mapping procedure therefore holds much potential to better understand the spatiotemporal states of visual information, thereby offering insight into how the early visual code shapes and refines higher semantic representations of our visual world.

Acknowledgements: James S. McDonnell Foundation grant (220020430) to BCH; National Science Foundation grant (1736394) to BCH and MRG.

12:30 pm

Rapid scene categorization is not purely feed-forward: An EEG investigation of scene gist facilitation by sequential predictions

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Rapid scene categorization is typically argued to be purely feed-forward. Yet, when navigating in our environment, we usually see predictable sequences of scene categories (e.g., offices followed by hallways, parking lots followed by sidewalks, etc.). Previous work showed that scenes were both easier to recognize, and to discriminate from phase-randomized noise, when shown in ecologically valid, predictable sequences than in randomized sequences (Smith & Loschky, 2019). But, when in scene processing do sequential predictions facilitate scene categorization? We examined this question using EEG. Participants saw scenes in either spatiotemporally coherent sequences (first-person viewpoint of navigating, from, say, an office to a classroom) or their randomized versions. Participants saw 288 scene RSVP sequences (each 1 target and 9 primes), while we recorded their event-related potentials (ERPs). Participants had to categorize one randomly selected target image on each trial, in an 8-AFC task. We found reduced ERP amplitudes for targets in coherent sequences roughly 140 milliseconds after image onset--when ERPs typically first index rapid scene categorization--and during the N300 and N400 components, suggesting both reduced identification costs and semantic integration costs in coherent sequences. Interestingly, such ERP amplitude reductions were predicted by low-level visual similarity between sequential prime-target pairs, suggesting that visual similarity might explain the reduced processing costs in coherent sequences. To test this hypothesis, in Experiment 2, we reran Experiment 1 behaviorally, but replaced the targets with noise images, and asked participants to predict the categories of the missing scenes. Target scenes were more predictable in coherent sequences. Importantly, the correlations of Experiment 2 image predictability with Experiment 1 ERP amplitudes (from 140-450 ms) were greater than for image similarity with ERP amplitudes. Thus, contrary to purely feed-forward accounts of rapid scene category recognition, both predictions for an upcoming scene category and visual similarity between successive scenes facilitate scene “gist”.

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12:45 pm

Object representations in visual cortex are scaled to account for viewing distance during visual search

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Humans are remarkably proficient at finding objects within a complex visual world. It has been proposed that observers strategically increase their visual system’s responsivity to any object of interest, by pre-activating a visual representation of the target object during search preparation. Despite being widely accepted, this mechanism fails to account for an inherent property of real-world vision: the image that any given object will project on the retinae is unknown, as it depends on the object’s eventual location. For instance, the color and shape of the retinal image are determined by the illumination and viewpoint on the object, and –most dramatically– its size can vary by orders of magnitude depending on the distance to the object. How can preparatory activity in visual cortex benefit search in the real world, where the retinal image of an object is context-dependent? We addressed this question by testing whether human observers generate visual object representations during search preparation, and scale those object representations to account for viewing distance. In two fMRI experiments, (N=58) participants were cued to search for real-world objects at different distances within naturalistic scenes. We measured BOLD responses following the onset of the scene, from which the viewing

distance could be inferred, and analyzed a subset of trials in which –unexpectedly– no array of objects appeared. This allowed for isolating brain activity related to search preparation only. Using multivariate pattern analysis, we related the patterns of brain activity evoked during search preparation, to those evoked by viewing isolated objects of different sizes. The data show that (1) observers generate visual representations of their target object during search preparation in object-selective regions, and (2) scale these representations to flexibly account for search distance. These findings reconcile current theories on visual selection with the functional demands of real-world vision.

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1:00 pm

Evidence for a ventral visual stream in the pulvinar

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The pulvinar is richly interconnected with visual and association cortices that support a variety of visual functions. Studies in non-human primates have shown that inferior and lateral regions of the pulvinar are connected primarily to early visual cortex, have a clear retinotopic organization, and are sensitive to low-level visual features. However, the pulvinar’s potential role in high-level visual functions such as scene perception and object recognition has been little studied. To address this gap, we investigated subcortical activity in the Natural Scenes Dataset (NSD). In NSD, 8 humans completed a visual fMRI experiment during which they were exposed to 9,000–10,000 unique natural scenes. Whole-brain fMRI data were collected at 7T with 1.8-mm resolution, ensuring high-quality measurements from subcortical regions. We fit population receptive field (pRF) models to individual voxels, systematically evaluating different stimulus features (contrast, saliency, faces, bodies, foreground, background) that might be encoded in voxel responses. The pRF analysis confirmed that the LGN and inferior-lateral portions of the pulvinar are selective for contrast presented in the contralateral visual hemifield and have clear retinotopic organization, consistent with prior work. Interestingly, the analysis revealed a subregion of the pulvinar, located medial and posterior to the contrast-selective region, that is selective for bodies and faces presented in the contralateral visual hemifield. In-between these two subregions, we also identified a region of the pulvinar sensitive to foreground objects in general. These results indicate a role of the pulvinar in object recognition, specifically in the processing of high-level visual features such as faces and bodies. The functional organization of the pulvinar appears to parallel the hierarchical organization of ventral visual cortex, and suggests that the classic two-stream model of the visual system extends to subcortex.

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1:15 pm

The Ganzflicker experience: A window into the mind's eye

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The mind's eye is an elusive subjective experience; as such, most of us are unaware that there is more than one way to imagine the sensory world. People who have no mind's eye (aphantasia) must rely on non-sensory imagination (symbols, words) to simulate the world, whereas people who have an extremely vivid mind's eye (hyperphantasia) may get lost in visual fantasies on a daily basis. Imagery is now thought to be a spectrum, with different abilities offering different advantages and disadvantages in daily life and across the lifespan. An elegant method we adapted as a window to the rich individual differences of the mind's eye is "Ganzflicker", a rhythmic alternation of colors that can elicit immediate and vivid pseudo-hallucinations. Over the past year, over 200 individual Ganzflicker experiences were collected from people across the spectrum of imagery abilities, both from anonymous internet volunteers and a student sample. First, results point toward a bimodal distribution of imagery ability, with aphantasia (no-to-low imagery) as a distinct spectrum from (moderate-to-vivid) imagery. Bayesian analyses provide extremely strong evidence that people with aphantasia are less prone to pseudo-hallucinations compared to people with imagery. Among those who have visuals, people with imagery see more vivid and complex pseudo-hallucinations, and experience more altered states of consciousness, compared to people with aphantasia. We propose that aphantasia may provide a buffer against induced anomalous percepts. This study has important implications for understanding pathological hallucinations, which are unpredictable and debilitating to normal life.

Acknowledgements: This work was funded by the Leibniz Association, SAS-2015-LIN-LWC

Perceptual Organization

Tuesday, May 25, 10:30 am - 12:00 pm EDT, Talk Room 1 Join Zoom Webinar

Moderator: Dirk Walther, Toronto

10:30 am

Border ownership selectivity in area V4 occurs first in infragranular layers

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Border ownership neurons in primate visual cortex (present especially in areas V2 and V4) encode which side of a border belongs to an object, even if the defining stimulus information falls well outside of the classical receptive field. These signals are thought to be critical for scene segmentation and object recognition, but it remains unclear how they are computed. Important missing pieces of information are the occurrence and timing of border ownership signals in different cortical laminar compartments. Here we addressed this issue by mapping border ownership selectivity across cortical layers using 32-channel laminar probes to record responses from well-isolated units in extrastriate visual area V4 in the rhesus macaque. By replacing the native dura with a transparent artificial dura we were able to position the probes orthogonally to the cortical surface. We used current source density analysis of stimulus-evoked local field potentials to identify the granular (input) layer as the current sink with the shortest latency, and locate the units recorded from to supragranular, granular or infragranular layers. We then measured spiking activity evoked by square stimuli presented on a uniform background. The square was positioned such that only one of its borders fell in the classical receptive field of each neuron. Border ownership was thus defined by stimulus features outside of the classical receptive field. We find that border ownership selectivity occurs first in the infragranular layers, before it appears in the granular and the supragranular layers. This suggests that border ownership signals are not inherited in a feedforward manner from upstream areas, but instead established de novo, or inherited through cortical feedback from downstream areas, in V4 infragranular layers. These infragranular layers include neurons that project to upstream cortical areas, raising the possibility that these signals sculpt border ownership selectivity in V2.

Acknowledgements: This work was supported by a fellowship from the George E. Hewitt Foundation for Medical Research to TPF and NIH grants K99EY031795 (TPF), P30EY019005 and the Fiona and Sanjay Jha Chair in Neuroscience (JHR).

10:45 am

Object completion with stochastic completion fields predicts human behavior in recognizing degraded object drawings

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Biederman & Cooper (1991) showed that observers were better at classifying degraded line drawings of objects when shown only contour junctions than when shown only middle segments. We here provide an account of these results based on a low-level algorithm for object completion. The human visual system infers geometry not only for visible but also for occluded contours and surfaces. This provides a central theme to figural completion which lays out a computational framework to estimate paths that connect a set of boundary fragments. In our model, we use the Fokker-Planck Equation to extract a set of points with assigned orientations. These points represent the sources and sinks for a stochastic completion field (SCF) algorithm (Williams and Jacobs, 1995). The SCF algorithm produces a distribution of possible completion fields, where each field is a probability density function (PDF) that enables us to score each possible completion path. We tested the algorithm on the Snodgrass and Vanderwart (1980) dataset of 260 manually traced line drawings of objects. The traced objects were separated into two half images; one half with contour segments containing junctions, and the other with segments between junctions. We attempted to complete the half-drawings using the SCF algorithm. The completions replicated the original, intact drawings more faithfully for the half-drawings with junctions than those with middle segments. Our computational results show that contour completion is easier in objects with junctions than with middle segments, which aligns with Biederman & Cooper's behavioural result. Ultimately, the SCF is a method that is potentially useful for predicting which types of incomplete line drawings can be more easily

completed by the human visual system. Moreover, SCF may form the computational basis for an image-computable implementation of the Good Continuation Gestalt grouping rule.

Acknowledgements: University of Toronto

11:00 am

Perceptual Grouping and Selection Strategies in an Enumeration Task

Maria Kon[1] mkon@purdue.edu, Gregory Francis[1]; [1]Purdue University

Perceptual grouping and selection are fundamental properties of visual perception, but their mechanisms remain poorly understood. Francis et al. (2017) and Kon and Francis (2020) proposed a neural network model that implements these properties. According to the model, a subject uses a particular grouping strategy that promotes performance on a given task and stimulus set. A grouping strategy consists of a connection strategy for connecting elements in a scene and a selection strategy that specifies the timing, location, and size of attentional spotlights. Building on this work, we apply the model to a visual enumeration task in Trick and Enns (1997). On each trial the task was to report the number of diamonds in an array, where there could be 1 to 8 diamonds and 0, 4 or 8 square distractors. The shapes were either drawn by lines or indicated by dots positioned at shape corners. In the dot shape condition, participants could only subitize (preattentive visual numerosity) when there were 1 to 3 targets and no distractors. Trick and Enns (1997) concluded that element clustering, i.e., the process of linking some elements (and not others) into units, is distinct from shape formation, i.e., the process of determining cluster shape. We modeled this task and results by identifying grouping strategies that closely match human performance for all distractor and shape conditions. Interestingly, the relatively flat slopes across mean response times for conditions with 1 to 3 targets and no distractors, which are regarded as indicative of subitizing, can be produced by this model even though it lacks a formal subitizing process. Additionally, the identified strategies indicate that the dot shapes require something like element clustering, i.e., connections, to be efficiently selected and counted. Thus, the model supports the claim that a distinct element clustering process is involved in this task.

11:15 am

Differential processing of reflection and rotation symmetries in visual textures

Rachel Moreau[1] rachelm7@yorku.ca, Nihan Alp[2], Alasdair Clarke[3], Erez Freud[1], Peter Kohler[1]; [1]York University, Canada, [2]Sabancı University, Turkey, [3]Essex University, UK

Symmetries of various types are prevalent in the natural world. Psychophysical studies show that reflection symmetry (found in faces, bodies) can be detected preattentively, requiring less cognitive resources than other symmetry types such as rotation (found in flower petals, snowflakes). The distinction between symmetry types is important to our understanding of how symmetries contribute to perception of scenes and objects. Visual search has previously been used to probe the distinction between serial and parallel processing of cues to object shape (Enns and Rensink, 1991). Here we employ a visual search paradigm with symmetries that are embedded within regular textures. Our goal is to enhance our understanding of the mechanisms responsible for perceiving symmetries in textures, and differentiate between reflection and rotation symmetry. Based on previous findings, we hypothesize that reflection will elicit more parallel processing than rotation. We conducted two visual search experiments in which participants were presented with regular textures consisting of arrays of tiles containing symmetries. Participants were asked to report the presence of a target tile that had no symmetry and thus disrupted the regularity. We used four different array sizes (total # tiles: 9, 16, 25, 36), and trials with each array size were presented in an interleaved fashion. In Experiment 1, the non-target tiles contained reflection symmetry (N=133), while in Experiment 2 they contained rotation symmetry (N=148). In both experiments we found that accuracy was reduced and RT was increased as array sizes got larger, consistent with serial processing. Importantly, this array size effect was reduced for reflection symmetry relative to rotation symmetry. These results suggest that reflection symmetry elicits more parallel processing than rotation and that the two symmetry types can be differentiated in terms of the mechanisms required for perceiving them.

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11:30 am

Visual ensemble representations in Deep Neural Networks trained for natural object recognition

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Humans can quickly pool information from across many individual objects to perceive ensemble properties, like the average size or color diversity of objects. Such ensemble perception in humans is thought to occur extremely efficiently and automatically, but how it arises in the first place is unknown. Does ensemble perception arise because the visual system must solve many different types of perceptual problems, or are ensemble properties represented even in a system with the sole goal of recognizing individual objects? We used an artificial visual system—a deep neural network (DNN)—to determine whether the ensemble properties of average size and color diversity were present in a network pre-trained to recognize only individual natural objects. We presented the network with new images that were completely different from its training set: images of white circles of different sizes (randomly chosen from a specified range) or letter arrays containing four colored consonants with each letter drawn either from a broad sample of 19 colors (high diversity) or a randomly selected range of six adjacent colors (low diversity). Therefore, the ensemble properties of interest were a summary statistic for the whole image and not recoverable from any individual element. We tested whether a ResNet50 neural network could predict the average size or distinguish high vs low color diversity arrays by using the activations from different layers as input to a linear regressor and a linear classifier (SVM). We found that the network activations were highly accurate at predicting the average size and identifying the color diversity, even at the earlier layers in the network. In contrast, information about individual object features (object size) increased in the deeper layers. This demonstrates that artificial visual systems trained to only recognize individual objects also extract ensemble properties of multiple objects extremely early in visual processing.

11:45 am

Can I trust in what I see? – EEG evidence for reliability estimations of perceptual outcomes

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Background: During observation of ambiguous and low-visibility stimuli perception becomes unstable and may alternate between different interpretations. Tiny low-level changes can disambiguate such a stimulus and/or increase its visibility and thus stabilize its percept. Methods: We compared event related potentials (ERPs) evoked by ambiguous and low-visibility stimuli with disambiguated and high-visibility stimulus variants across different visual categories (geometry, motion) and complexity levels (up to emotional face expressions). Results: Disambiguated and highly visible stimulus variants cause stable percepts and evoke much larger amplitudes of two positive ERP components than ambiguous stimuli ($d > 1$). This pattern of ERP results is highly consistent both in space and time across very different categories and complexity levels. Discussion: The generality of our findings points to high-level mechanisms: We postulate that a meta-perceptual/cognitive inference unit evaluates the reliability of perceptual constructs beyond sensory details. Small ERP amplitudes reflect high small amplitudes low perceptual reliability. I will discuss our results in the context of predictive coding theories as ERP correlates of prediction success with remarkably large effect sizes.

Acknowledgements: We thank the Deutsche Forschungsgemeinschaft (KO 4764/1-1, TE 280/8-1) and the Neurex (Neuroscience Upper Rhine Network) for financial support.

Talk Sessions >

Eye Movements: Extra-retinal processes, scanpaths

Tuesday, May 25, 10:30 am - 12:00 pm EDT, Talk Room 2 **Join Zoom Webinar**

Moderator: Martin Rolfs, Humboldt University

10:30 am

Foveal remapping of motion in area MT of the marmoset monkey

Shanna H Coop[1] shannahcoop@gmail.com, Jacob L Yates[2], Jude F Mitchell[1]; [1]University of Rochester, [2]University of Maryland College Park

Human vision relies on rapid eye movements (saccades) to bring peripheral visual targets to the fovea for high resolution inspection. Tracking stimuli across saccades is thought to involve a predictive visual remapping that anticipates the sensory effect of saccades, called visual remapping, and for saccade targets brought to the fovea, foveal remapping. At the neural level, visual remapping is found at later stages of processing involved in saccade planning but less so in early visual cortex. However, Recent EEG and fMRI studies suggest that foveal remapping may specifically involve early visual cortex. In particular, foveal remapping is thought to include feature-specific information about the saccade target and can even lead to misperception of a peripheral target that disappeared in saccade flight as being at the fovea (i.e., foveal ghosts). But localization to early visual cortex with EEG and fMRI is limited. Using single unit neurophysiology we examined if neural activity in the middle temporal (MT) area reflects a foveal remapping of stimulus motion. Marmoset monkeys made a saccade from central fixation point to one of two or three equally eccentric motion dot fields. We included three gaze-contingent conditions: “predictive” where the stimulus was unchanged during the saccade and thus could be anticipated at the fovea, “unexpected” where the motion direction changed, and “blanked” where the stimulus disappeared. Using linear arrays we recorded from MT foveal populations and trained a decoder to report the post-saccadic foveal motion from each trial. We found that we could decode the motion direction faster when the target was “predictive” versus “unexpected”. Further, on “blanked” trials we could decode the anticipated motion. These results demonstrate that foveal MT neurons receive feature predictions about a saccade target before it enters their receptive fields, providing the first single unit evidence of foveal remapping in early visual cortex.

Acknowledgements: NIH EY030998 (SHC,JFM) ; K99 EY032179-01(JLY)

10:45 am

Predictive enhancement of saccade target features in the pre-saccadic center of gaze

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While pre-saccadic sensitivity modulations at the target of an eye movement have been studied extensively, little is known about the concurrent development of visual sensitivity in the center of gaze. Using a dynamic noise paradigm, we demonstrate that defining features of an upcoming saccade target predictively alter foveal perception. We asked observers to detect an orientation-filtered pink noise patch (the probe; presented on 50% of trials) in their center of gaze while they prepared a saccade to another orientation-filtered patch (the target). Probe and target exhibited one of two possible orientations, such that the probe was oriented either congruently or incongruently to the target. Both stimuli were smoothly embedded in a stream of pink noise images covering the entire screen. We found that foveal hit rates decreased continuously during saccade preparation, when attention is known to shift to the target. Crucially, this decrease was less pronounced for target-congruent than for target-incongruent probes starting 200 ms before saccade onset. When generating a false alarm (FA), observers reported perceiving target-congruent probes more often than incongruent ones. Reverse correlations revealed that FAs were by no means unsystematic but relied on an incidental, high energy of the reported orientation in the foveal noise region. Notably, for observers to perceive a target-incongruent probe in the foveal noise, strong and unambiguous evidence for its orientation was required. Weaker foveal evidence for the target orientation was sufficient to trigger congruent FAs. These correlations between noise content and response behavior were specific to the foveal noise region. Combined, our results demonstrate that, during saccade preparation,

sensitivity to target-congruent features increases in the very center of gaze. To our knowledge, this constitutes the first behavioral evidence for a predictive, foveal sensitization to soon-to-be fixated features—a mechanism that may support the continuous perception of saccade targets across eye-movement-induced displacements.

Acknowledgements: This research was supported by the Deutsche Forschungsgemeinschaft (grants RO3579/8-1, RO3579/9-1, and RO3579/12-1 to M.R.)

11:00 am

Fine spatial judgements driven by extra-retinal knowledge of fixational eye drifts

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During normal fixation, the human eyes move incessantly, following seemingly random trajectories. This motion known as ocular drift, has long been assumed to result from imprecise motor control and to be estimated by the visual system from the resulting image motion on the retina. Several lines of evidence now indicate that drift is controlled (Intoy and Rucci, Nat. Comm., 2020). Thus, the question emerges of whether the visual system also has access to extra-retinal information about drift motion. To investigate this question, we designed a task in which extra-retinal information about drift is required for a Vernier judgment. In a 2AFC task, human observers (N=7) reported the spatial relation between Vernier stimuli that were displayed in a gaze-contingent manner as the eye normally drifts. Stimuli were viewed through a thin slit aperture which moved with the eye, enabling exposure of only a vertical strip on the retina, so that the two Vernier bars were vertically aligned on the retina. Thus, the retinal image contains no Vernier offset, but a percept of displacement could arise if the subject has access to extra-retinal knowledge of the direction of ocular drift between the flashes. Special care was taken to eliminate all spatial cues, by showing stimuli in complete darkness and using a custom-developed LED display with no visual persistence. All subjects were able to accomplish the task with Vernier gap of just 2’ and exhibited higher performance as the gap increased. Data are well predicted by a Bayesian model that incorporates prior knowledge of drift motion as a Brownian motion process. These results indicate that humans have access to extraretinal drift information and use it in establishing spatial representations.

Acknowledgements: This work was supported by NIH grants EY18363 (MR) and EY07977 (JV).

11:15 am

New enhancements to the DeepGaze models for a better understanding of human scanpaths

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The family of DeepGaze models comprises deep learning based computational models of freeviewing overt attention. DeepGaze II predicts freeviewing fixation locations (Kümmerer et al, ICCV 2017) and DeepGaze III (Kümmerer at al, CCN 2019) predicts freeviewing sequences of fixations. The models encode image information using deep features from pretrained deep neural networks to compute a spatial saliency map, which, in case of DeepGaze III, is then combined with information about the scanpath history to predict the next fixation. Both models have set the state of the art in their respective tasks in the last years. Here, we improve the performance of both models substantially. We replace the backbone deep neural network VGG-19 with better performing networks such as DenseNet. We also improve the architecture of the model and the training procedure. This results in a substantial performance improvement for both DeepGaze II and DeepGaze III and sets a new state of the art for freeviewing fixation prediction and freeviewing scanpath prediction across all commonly used metrics. We further use the improved DeepGaze III model to better understand human scanpaths. For example, we quantify the effects of scene content and scanpath history on human scanpaths. We find that, on the MIT1003 dataset, scene content has a substantially larger effect on fixation selection than scanpath history and that there are only very subtle but measurable interactions between scene content and scanpath history that go beyond a scalar saliency measure. Furthermore, we are able to disentangle the central fixation bias into contributions that are driven by image content, by the initial central fixation, and by a remaining effect that cannot be explained from these two sources. Taken together, the improved DeepGaze models allow us to analyze

human scanpaths in ways that are not possible without high-performing deep learning models.

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11:30 am

Individual fixation preferences within a face generalise to other kinds of objects

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The typical landing point of the first fixation towards a face is just below the eyes. This is compatible with a foveated ideal observer, aiming to maximise information about facial identity and expression. However, there are reliable individual differences in the exact height of this landing point and these differences are performance-maximising for the individual. It is unclear whether this variation is due to the matching of individual face templates or to individual foveation, i.e. the individual distribution of resources across the visual field. We hypothesized that variance in foveation would predict an extension of fixation differences to other types of objects. A sample of 101 observers freely viewed 700 natural scenes. We extracted each fixation landing on a given face or non-face object first and calculated their relative height within the object. Results confirmed considerable individual differences for the relative height of face directed fixations and – crucially – also for fixations towards non-face objects. Importantly, both were highly correlated with each other ($r = .88$), showing that observers fixating higher or lower within a face show a similar tendency for other kinds of objects. Control analyses confirmed the consistency of these tendencies across images, image quadrants and experimental sessions separated by weeks. These results show that idiosyncratically preferred fixation locations generalise from faces to other types of objects and support the hypothesis they are related to general differences in foveation. We plan to further test this hypothesis by probing whether the preferred height of fixation reflects individual anisotropies in visual crowding and cortical magnification.

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Multisensory Processing

Tuesday, May 25, 1:00 - 2:30 pm EDT, Talk Room 1 Join Zoom Webinar

Moderator: Viola Stoermer, Dartmouth

1:00 pm

Seeing sounds: Brain mechanisms underlaying auditory contributions to visual detection

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How auditory information interacts with visual detection is a recurrent question in visual neuroscience. Whereas some studies propose that sounds interact automatically with incoming visual input, others instead claim that audiovisual interactions are dependent on top-down controlled processes like attention. In this study, we recorded magnetoencephalography (MEG) data while participants performed a visual detection task (where the audiovisual events were task-relevant) or a working memory task (where the audiovisual events were task-irrelevant). We trained multivariate pattern analysis classifiers and tested them at different time points to characterize how auditory information shaped visual stimulus representations over time in each task. Our results showed that sounds interact with visual detection via two different mechanisms. First, a mechanism by which observers actively used the auditory stimulus to orient their attention to the target onset, maintaining a stable representation of the visual stimulus along the whole trial. This mechanism allowed participants to improve their visual sensitivity and it was not automatic, as it required participants to attend the audiovisual signals. Second, a mechanism by which sounds elicit a neural response pattern akin to the one evoked by an actual visual stimulus. This latter mechanism was associated with an increase in false alarms and it is automatic since it was independent of participants attention to the audiovisual signals. This work shed light on a classic debate in regard to the automaticity of auditory dependent modulations of visual detection by showing that 1) sounds improve visual detection sensitivity via a top-down controlled mechanism; and 2) changes in criterion (i.e. signal detection theory parameter) due to sound presentation in visual detection experiments do not merely reflect decisional biases. Instead, our results suggest that sounds automatically evoke neural activity patterns that could be interpreted by the brain as a veridical visual stimulus.

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1:15 pm

Auditory Context Alters Visual Perception

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Visual inputs are often obscured, distorted, or ambivalent, and to form meaningful representations of incoming information, our visual system relies not only on the visual features of the object itself but takes into account the surrounding context. Most studies have focused on how visual context influences visual object perception, and it is less clear how concurrent auditory information about objects—the sound of a lawnmower, or the whistling of a tea kettle—influences what objects we see and how we experience them. Here, we investigate whether naturalistic sounds modulate the representation of visual objects. We used a visual discrimination task and a novel set of ambiguous object stimuli that were paired at random with related or unrelated sounds. Specifically, we created ambiguous stimuli by morphing together the features of two objects (Object A, Object B, e.g., a hammer and a seal), and presented these ambiguous morph stimuli with naturalistic sounds that were related to either Object A or B. Visual objects and sounds were presented simultaneously, and at the end of each trial, participants indicated what object they saw using continuous report. Overall, we found that sounds biased visual object recognition, such that the perceptual

representation was pulled towards the object features that matched the sound (Exp. 1a-1b). For example, the same ambiguous hammer-seal object would appear more seal-like when paired with the sound of seal barking, but more hammer-like when paired with the sound of a hammer hitting. In various control experiments, we show that this effect is not driven by response bias (Exp. 2a-2b), and not due to a general effect of expectation (Exp.3). These results indicate that visual object representations are biased by contextual auditory information due to the continuous integration of auditory and visual information during real-world perception.

1:30 pm

How blurry are echoes? Quantifying the spatial resolution of echoic vs. visual object perception

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Recent research has explored the use of active echolocation by blind individuals, who, by generating mouth-clicks, elicit echoes and use them to perceive and interact with their surroundings. In prior work we showed that expert practitioners can distinguish the positions of objects separated by as little as ~1.5°, the approximate threshold of visual letter recognition at 35° retinal eccentricity. They can also echolocate household-sized objects, then distinguish them haptically from a distractor with significantly above-chance accuracy (~60%). Here we investigated whether the spatial resolution of crossmodal echo-haptic object discrimination is similar to that measured for localization. We found that blindfolded sighted participants tested on the same crossmodal match-to-sample design performed similarly, but with greater inter-individual variability. Performance was similar for both common household objects and novel (Lego) objects of arbitrary shape. This suggests that some coarse object information a) is available to both expert blind and novice sighted echolocators, b) transfers from auditory to haptic modalities, c) is not dependent on prior object familiarity, and d) may require a larger angular size than was subtended by our test objects. Thus, we repeated the match-to-sample experiments using stimuli enlarged by 50% along each dimension. Preliminary results do not show improved performance with larger object size; feedback after each trial in future sessions may improve accuracy. Next, we aimed to directly estimate the equivalent visual resolution of echoic object perception. In a pilot experiment, sighted participants examined target objects visually at 35° eccentricity and, subsequently, identified the target haptically. Performance was ~85%, suggesting that haptic recognition is better informed by visual object information at 35° than by object echoes at the scales we tested. Manipulating visual blur to equate visual and echoic performance will reveal more precisely the spatial resolution of echo-based object perception.

Acknowledgements: This work was supported by an NIH T32 Training Grant (to ST); The Foundation for Ophthalmology Research and Education – International (to ST); UCA AURS summer research award (to ME, AP); UCA Faculty Research Grant (to AP)

1:45 pm

The Beep-Speed Illusion: Non-Spatial Tones Increase the Perceived Speed of Visual Objects

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Coinciding auditory information alters early processing of visual scenes, however, the interplay between audio-visual integration and selective visual attention is far from being understood. Here, we introduce the beep-speed illusion revealing both the impact of audio-visual integration on attentional guidance as well as perceptual consequences following the selective allocation of visual attention toward audio-visually synchronized objects. We observed the illusion with displays involving two simultaneously moving objects that change their motion trajectories occasionally, but only the direction changes of one object are accompanied by spatially uninformative tones. Whereas this object always moved with 4.5 deg/s, we varied the speed of the other, purely visual object across trials. The task of the participants was to indicate which of the two discs moved faster. From these answers, we calculated the point of subjective equality (i.e. the speed of the visual object at which both objects appeared to move at the same speed). We observed a selective increase in perceived object speed (4-8%) of the audio-visually synchronized object (Exp. 1a) which persists when preventing eye movements (Exp. 1b). When the coinciding tones were replaced with temporally matched color changes

of the synchronized object, we observed a comparable illusory increase in perceived speed, whereas presenting color changes of a surrounding frame instead of tones had no effect (Exp. 2). Finally, the illusion even emerged with spatially incongruent tones (Exp. 3). Taken together, our pattern of results suggests that audio-visual synchrony attracts visual attention towards the coinciding visual object, leading to an increase in speed-perception. Although future research is necessary to explore the boundary conditions of the beep-speed illusion, the striking phenomenology as well as quantifiability of the illusory increase in perceived object speed render this illusion a promising road for a better understanding of the interplay between audio-visual integration and attentional selection.

2:00 pm

Assessment of the Bayesian hypothesis for visual-vestibular cue combination

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For locomotion through the visual world in which we operate, a core issue is to conceptualize how its 3D structure is encoded through the neural computation of the multiple depth cues and their integration to a unitary representation of the changing scene. The overall percept must be derived from the combination of all available depth cues, but a simple linear summation rule across the array of different depth cues, would massively overestimate the perceived depth in the scene in cases where each cue alone provides a close-to-veridical depth estimate. On the other hand, a Bayesian averaging, or 'modified weak fusion', model for depth cue combination does not provide for the observed enhancement of perceived depth from weak depth cues. To assess performance with multisensory cues, the case of perceived heading from motion in depth conveyed by visual and vestibular cues is considered, based on data kindly provided from a published behavioral study with monkeys (Dokka, DeAngelis & Angelaki, 2015, J Neurosci), where the perceived heading was biased by an auxiliary cue of the lateral motion of a visually-defined sphere, with a juice reward for a correct response to whether the physical heading was to the left or right. Theoretical distributions for Bayesian analyses were derived from the individual trial data. The individual heading estimates were substantially biased by the decoy sphere motion for each of the visual and vestibular cues alone, but much less so when the cues were combined. An Obligate Bayesian rule for the cue combination calculated for these data could not account for the observed reduction in the combined heading bias. The data are, however, consistent with a Selective Bayesian rule, in which the monkeys are assumed to be able to ignore the heading information in the visual modality if advantageous to do so.

2:15 pm

Decoding sounds in early "visual" cortex of the congenitally blind

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Complex natural sounds, such as bird singing, people talking or traffic noise, induce decodable fMRI activation patterns in early visual cortex of sighted blindfolded participants (Vetter, Smith & Muckli, 2014, Current Biology). That is, early visual cortex receives non-visual and potentially predictive information from audition. However, it is unclear whether the transfer of auditory information to early visual areas is an epiphenomenon of visual imagery or, alternatively, whether it is driven by mechanisms independent from visual experience. We acquired fMRI activity from 8 congenitally blind participants listening to different natural sounds, and derived boundaries of early visual areas V1, V2, and V3 by overlaying probabilistic retinotopic maps from sighted participants onto the reconstructed brain surfaces of blind participants. Using multi-variate pattern analysis, we decoded natural sounds in early "visual" areas of congenitally blind individuals who lack visual imagery. Thus, visual imagery is not a prerequisite of auditory feedback to early visual cortex. Furthermore, the spatial pattern of sound decoding accuracy in early visual cortex was remarkably similar in blind and sighted individuals, with an increasing decoding accuracy gradient from foveal to peripheral regions. This suggests that the typical organisation by eccentricity of early visual cortex develops for auditory feedback even in the lifelong absence of vision. The same feedback to early visual cortex might support visual perception in the sighted (Vetter, Smith & Muckli, 2014, Curr Biol) and drive the recruitment of this area for non-visual functions in blind individuals (Amedi et al., 2003, Nat Neurosci; Bedny, 2017, TICS).

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Visual Memory: Capacity, models, neural and encoding

Tuesday, May 25, 1:00 - 2:30 pm EDT, Talk Room 2 Join Zoom Webinar

Moderator: Stefan van der Stigchel, Utrecht University

1:00 pm

EEG decoding of categorical biases in working memory

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Previous studies demonstrated that visual representations in working memory exhibit biases in relation to the categorical structure of the stimulus space. For example, color representations are biased away from the nearest category border and orientation representations are biased away from the nearest cardinal axis. However, a majority of those studies are based on behavioral measures of working memory (e.g., delayed estimation), and thus it is unclear whether the bias is driven by the shift of representation per se or by the processes that translate the memory representations into a behavioral response. Here, the present study attempted to find evidence that the actual content of working memory is categorically biased even before a response is made using a recently developed EEG decoding method. In Experiment 1, EEG was recorded while participants were performing a simple location delayed estimation task. I found that the decoding of location was biased away from the nearest cardinal location, consistent with the biases observed in the behavioral responses. Follow-up analyses showed that the categorical bias started as early as the stimulus encoding stage, indicating that the categorical bias in behavior was originated from the perception of the stimulus. Experiment 2 replicated these findings using a 2AFC orientation working memory task where participants reported the remembered orientation using a button press to indicate which of the two probe items matched the orientation of the original sample object. Because the two probe items were simultaneously presented in locations different from the location of the sample object in the task, this result indicates that the categorical bias in decoding was not merely driven by a location-based response preparation strategy. Together, these results provide neural evidence that working memory representations themselves are categorically biased, imposing important constraints on the computational models of working memory representations.

1:15 pm

Small neuronal ensembles of primate lateral prefrontal cortex encode spatial working memory in two reference frames

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Single neurons in the primate lateral prefrontal cortex (LPFC) encode spatial information during working memory (WM). However, it is poorly understood whether ensembles of neurons of a certain size can encode memorized locations based on different frames of reference during spatial WM. We trained two rhesus monkeys on a modified version of the oculomotor delayed-response task. For each trial, animals fixated a dot displayed at one of sixteen different positions on the screen and a target transiently appeared for 1000ms. Animals maintained fixation for another 1000ms and upon extinction of the fixation dot they made a saccade to the remembered target location to obtain a reward. Such task design allowed us to analyze the data for remembered locations relative to the fixation dot (retinotopic frame), and relative to the target location (spatio-centered frame). We recorded the extra-cellular unitary/multi-unitary activity by implanting multi-electrode arrays in the dorso-lateral (dLPFC) and ventro-lateral (vLPFC) prefrontal cortices. We grouped trials by quadrants within each reference frame (RF), computed the average firing rate during the WM delay for each unit, and determined their spatial selectivity (Mutual information test). We then constructed neuronal ensembles of different sizes (n=1,…50) and trained linear classifiers to decode the visual quadrant that included the memorized cue position from each ensemble size, and across 20 decoding iterations. We found that ensembles of dLPFC and vLPFC

cells yielded decoding accuracies of 69% and 79% in the retinotopic RF, respectively, and 55% and 52% in the spatiotopic RF. Interestingly, the classifiers frequently based their performance on spatially selective units for the smaller ensemble sizes (n <= 5), and gradually reduce this proportion as the size of ensembles increased (n >= 6). Neuronal ensembles of small size in the LFPC could encode locations during spatial WM in the retinotopic and spatiotopic reference frames

Acknowledgements: We acknowledge grants from the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Canadian Institutes of Health Research (CIHR) to perform this study.

1:30 pm

Transforming Latent Descriptors into memory Representations: The TLDR model of working memory

Shekoofeh Hedayati[1], Brad Wyble[2]; [1]The Pennsylvania State University

Visual knowledge is an inseparable part of working memory (WM) that affects encoding of information (Baddeley & Hitch, 1974; Baddeley, 2000; Ericsson & Kintsch, 1995). For example, the number of familiar items that people can remember is more than unfamiliar items (Zimmer & Fischer; 2020). And, active long-term memory is known to be a key component of WM (Cowan 2017; Oberauer 2009). Yet, no computational model has explained the underlying mechanism between visual knowledge and WM. In this study, we used a generative deep learning network to build a neurally-plausible computational model of WM that we call it TLDR. The visual knowledge in the TLDR is represented by a modified Variational Autoencoder (VAE; Kingma & Welling, 2013) that compresses the visual information in multiple layers. The TLDR encodes visual information by flexibly allocating neural resources to create an actively stored representation in a binding pool (BP; Swan & Wyble, 2014). The stored information in the BP is then retrieved to recreate those latent representations that were generated at the time that the stimuli were perceived. Consistent with human behavior in memory tasks, the TLDR is capable of explaining the following aspects of WM: efficient storage of familiar shapes with the aid of visual knowledge, storing novel configurations (Lake et al., 2011), encoding relevant attributes (e.g., color, shape, etc.) with varying degrees of precision (Swan, Collins, & Wyble, 2016), storing categorical information along with visual details with minimal interference, showing interference when multiple items or attributes are encoded in one memory trace, and rapid tuning the encoding parameters to accomplish unexpected memory tasks. In general, the TLDR provides new insights on the representations of WM in relation to the visual knowledge.

1:45 pm

Serial dependency bias as memory averaging

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It has been established that perceptual reports are influenced by previously reported percepts, a phenomenon described as ‘serial dependency in perception’. For example, the reported orientation of a line grating is attracted towards the orientation reported in the previous trial. This process presumably promotes perceptual stability in a noisy and dynamic visual world by integrating visual information sampled from the same object at different points in time. Despite a recent surge in studies illustrating serial dependency effects, it remains unclear whether these biases arise during perception (i.e., stimulus encoding), or within memory (i.e., stimulus maintenance). To distinguish between these possibilities, we sequentially presented four oriented gratings in an n-back working memory task. Participants were retro-actively cued which of the four orientations they should reproduce. In addition to the classic serial dependency effect, our data showed that reports were also biased by subsequently presented orientations. When, for example, the second item in the sequence was the target, its reported orientation was not only influenced by the first item but also by the third and fourth items. This finding excludes the possibility that serial dependency biases arise solely during encoding, since reported stimuli were already stored in memory at the time subsequent, influencing stimuli were presented. Based on data from three studies we propose a new model of serial bias in vision, describing the behavioral report of a perceived target as the result of an attentionally modulated, weighted average between the actual target, task-relevant information preceding and succeeding the target, as well as previous behavioral reports. Supplementary materials such as pre-prints, data, stimulus, and analysis scripts can be found at https://osf.io/54abr/?view_only=2f67d292ed9e4ed6bc731da09b624069

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2:00 pm

A quantitative model of ensemble perception as summed patterns of activation in feature space

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Ensemble perception allows the limited capacity visual system to efficiently consolidate noisy input from the environment to construct reliable representations, guide attention and classify features or objects (Whitney & Yamanashi, 2018). Despite the importance of ensemble perception, there are few computational models that provide a formal, process-level account of ensemble perception across a range of experimental conditions and stimuli. This is the goal of the current work; specifically, we propose a novel ensemble model, which is motivated by a recent signal detection model of memory (Schurgin, Wixted, & Brady, 2020). According to the proposed model, items evoke distributed patterns of familiarity over feature space (e.g., a color evokes a pattern of familiarity over all color channels), and ensemble representations reflect the global sum of these signals across all items -- a location-independent distribution over what features are present. We then assume that individuals report on their memory of the ensemble by selecting the feature value that generates the maximum familiarity signal after the signals are corrupted by noise. We leverage this set of minimal assumptions to capture the entire distribution of individuals' errors on an ensemble continuous report task using solely those individuals' estimates of performance on a separate VWM task. That is, we account for the full distribution of errors on the ensemble task with zero free parameters. The ensemble model was assessed in three experiments in which individuals were probed on their memory for ensemble color, where we varied the number of items, color range, and presence of an outlier. To assess the generalizability of our modeling results across stimuli spaces, we evaluated the model for ensemble processing of shapes. We discuss our model and results in the context of current theories of ensemble perception and population coding models of ensemble representation and memory.

2:15 pm

Melting ice with your mind: Dynamic representation of physical states

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When a log burns, it transforms from a block of wood into a pile of ash. Such state-changes are among the most dramatic ways objects can change their appearance—going beyond mere changes of position or orientation. How does the mind represent changes of state? A foundational result in visual cognition is that memory extrapolates the positions of moving objects—a distortion called "representational momentum." Here, we exploited this phenomenon to investigate mental representations in "state-space." We created realistic animations of objects undergoing state-changes: ice melting, grapes shriveling, logs burning, etc. Participants observed interrupted segments of these animations, and then reported the last frame they saw using a slider. Four experiments showed representational momentum for state-changes, revealing dynamic representation of physical states. In Experiment 1, participants consistently reported a frame more "forward" in time (e.g., more melted) than they had actually seen. Experiment 2 showed that such representations are flexible, arising even for directions rarely encountered before: We included both forward- and backward-playing animations (e.g., both melting and "unmelting") and observed representational momentum in both directions (e.g., for backward animations, participants remembered the ice as more "unmelted" than it really was). Experiment 3 controlled for low-level motion cues by showing that even a single static frame elicits representational momentum: Participants who saw one frame of each state-change misremembered it as further along its implied state-transformation. This also indicates that the mind privileges the physically natural forward direction. Finally, Experiment 4 ruled out biases that may have arisen from the response method (slider adjustments) by replicating our earlier results using a two-alternative forced-choice paradigm. Taken together, our findings reveal that mental representations of a dynamic world actively incorporate such dynamic changes, and in surprisingly broad ways: Whether in position or state, the mind extrapolates how objects change.

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Face Perception

Tuesday, May 25, 8:00 - 10:00 pm EDT, Talk Room 1 Join Zoom Webinar

Moderator: William Hayward, U Hong Kong

8:00 pm

Focus Upper, Process Larger: Matching Eye- or Mouth-area can Change Face Holistic Processing Range

Xin Zhou[1] kedazhou@qq.com, Yu-Hao Sun[2], Zhe Wang[3], Xiteng Yang[4]; [1]Zhejiang Sci-Tech University

Previous study (Wang et al., 2019) showed that upper- and lower-half face might be differently involved in human face holistic processing. In this current study, we replicated and extended the finding above. In experiment 1, we used the partial designed composite-face task to test the two ways of holistic processing: the upper-to-lower and the lower-to-upper composite. Participants were asked to judge whether same or not a study face and a test face's upper-halves (or lower-halves) were after the two faces were presented successively. Results showed that the composite-face effect was stronger when the participants focused at the upper-half face relative to the lower-half face. In experiment 2, we investigated whether the range of holistic face processing changes when participants fixated at eye (in upper half face) or mouth (in lower half face). Using the perceptual field paradigm, we present a fusion face and then its original faces (a "central face" which was same with the fusion face in the eye or mouth and a "peripheral face" which was same with the fusion face in area outside the eye or mouth). Participants were asked to judge which was more similar with the fusion face. The more "peripheral face" was selected, the larger is the perceptual field size, which refers to the holistic processing range). Results showed that: (1) the perceptual field size was larger when participants fixated at the eyes than when they fixated at the mouth; (2) face inversion made perceptual field size small when either an eye or the mouth was fixated at. The findings suggested that the range of holistic face processing depends on the face area people focus on and the upper-half (e.g., eyes or an eye area) plays a different role from that of the lower-half (mouth area) of a face.

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8:15 pm

High familiar faces have both part recognition and holistic processing advantages

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Previous studies reported that people recognize familiar faces better than unfamiliar faces(Jenkins, White, Van Montford & Burton, 2011). Does face part-based and/or holistic processing play a role in it? Wang and her colleagues (2015, 2019) in studies for face other-race effect (ORE) and species-specific effect (SSE) found that both part-based and holistic processing were strengthened, in a region-selective (i.e., eyes region vs. mouth region) way, by people daily experience accumulation. In this current study, we examined whether both part-based (probably region-selective) and holistic processing contribute to face familiarity effect. Three levels of familiar faces were used. They were classmates' faces (high familiar), schoolmates in the same department but different classes (middle familiar), and schoolmates in different departments (unfamiliar). Using an old/new task, Experiment 1 found high familiar eyes recognized better than middle familiar or unfamiliar faces ($p=0.004$, 0.001, respectively), but not for mouth recognition, suggesting a part-based region-selective familiarity effect. Using the "Perceptual field" Paradigm (Van Belle et al., 2015), Experiment 2 found that high familiar faces have strongest inversion effect ($ps<0.001$, <0.05, >0.35, in high familiar, middle familiar, and unfamiliar faces conditions, respectively), suggesting face holistic processing plays a role in face familiarity effect. The experience-based holistic processing hypothesis for face recognition was supported.

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8:30 pm

Idiosyncratic eye-movement patterns modulate holistic processing of faces: evidence from the composite face effect and the inverted face effect

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It is well established that faces are processed holistically, with the face inversion paradigm and the composite face paradigm two being widely used tasks to demonstrate this mode of processing. However, many recent studies have found that individuals differ in their eye movements to faces, and little is known about whether these differences in eye movements modulate holistic processing. To investigate this issue, participants were asked to complete the upright (or inverted) face identification task and the top (or bottom) cued composite face task. Using the Eye Movement analysis with Hidden Markov Models (EMHMM) approach to analyze their eye movements, participants were clustered into two groups on the basis of their eye movement patterns during the upright face identification task, with an upper-focused group who preferred to look at the upper half of a face (such as the eyes), and another lower-focused group who preferred to look at the nose or the mouth of a face. These two groups showed no significant difference in the size of the face inversion effect. But in the composite face task, the upper-focused group showed a stronger composite effect for matching the upper halves of faces than the lower halves, while the lower-focused group had similar magnitudes of composite effect between judging the upper half and the lower half conditions. Thus, holistic face processing is influenced by one's preferred face-scanning pattern.

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8:45 pm

Visual information sampling of faces by super-recognisers

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Individual differences in face recognition accuracy are likely to be linked to the way visual information is sampled and processed. Here we compared visual sampling of super-recognisers (SRs) – individuals that achieve the highest levels of accuracy in face recognition tasks – to typical viewers, using a novel gaze-contingent technique. Participants performed a face recognition task in which they learned and recognised novel faces while their gaze position was recorded. The face on the screen was modified in real-time to constrict the information around the gaze position at different aperture sizes. Super-recognisers displayed superior recognition accuracy for all but the smallest aperture viewing sizes. Underlying this superiority are qualitative differences in visual sampling: (i) SRs exhibited greater distribution of fixations across face images, suggesting enhanced visual exploration; (ii) SRs focused less on the eye region; (iii) SRs produced more fixations to the central region of faces. Importantly, these differences were most apparent in the learning phase of the experiment, suggesting that the superior accuracy of SRs was founded on enhanced encoding of faces into memory. Together, our results point to a process whereby SRs construct a more robust memory trace by accumulating samples of complex visual information across successive eye movements. Because super-recognisers display superior accuracy with restricted viewing – while also showing fixation patterns that are associated with holistic processing – SR's superior performance appears to achieved by combining both local and global sources of information in memory representations.

9:00 pm

Intact gaze processing in developmental prosopagnosia

Zoe Little[1] zoe.little@vuw.ac.nz, Colin J. Palmer[2], Tirta Susilo[1]; [1]Victoria University of Wellington, [2]University of New South Wales

The eyes of other people subserve two core functions in human social cognition: gaze perception and facial identity recognition. Here we report four experiments that investigate whether various aspects of gaze processing can be intact when identity processing is impaired in developmental prosopagnosia (DP). Experiment 1 (N = 102 DPs, 97 controls) measured perception of strabismus, which requires judgment of gaze direction from the two eyes. Experiment 2 (N =

101 DPs, 97 controls) measured the Wollaston illusion (whereby perceived eye gaze is pulled by head rotation), which requires perceptual integration of eye and head direction. Experiment 3 (N = 45 DPs, 45 controls) measured gaze discrimination and gaze adaptation, which reflects sensitivity to gaze direction and its sensory representations. Experiment 4 (N = 18 DPs, 22 controls) measured serial dependence in gaze perception, which reflects temporal integration of gaze direction and its perceptual stability. Despite their severe and lifelong deficits at recognising identity, DPs showed normal gaze processing across all experiments. These results demonstrate the functional specificity of gaze processing and imply that gaze perception is carried out by dedicated mechanisms not used for processing identity. Our findings align with models of face processing that posit distinct pathways for gaze and identity analysis, and further clarify the selectivity of face processing dysfunctions in developmental prosopagnosia.

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9:15 pm

Social orienting of attention: A meta-analytic review of the gaze-cueing effect

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Reflexively following the eye gaze of others is thought to be a fundamental mechanism of human social cognition. In line with this, a gaze-cueing effect – whereby, healthy adults respond faster to peripheral targets presented at gazed-at rather than gazed-away-from locations – has been observed in the empirical literature. However, from both a methodological and theoretical perspective, many important questions remain about the potential role of moderator variables in understanding this effect. To directly address these, we conducted the first meta-analytic integration of the gaze-cueing literature. Integrating data from 3693 healthy adult participants from 112 independent samples, we found a small but significant gaze-cueing effect, g = 0.23. Although robust, emerging at all levels of each of the task parameters we examined, the magnitude of this effect was moderated by three key variables: namely, whether direct-gaze cues had preceded each directional gaze-cue or not, whether gaze-cues had disappeared before targets appeared or not, and whether the task had been to detect, localize, or categorize targets. The magnitude of the gaze-cueing effect also appeared to vary as a function of the emotional expression of the cue and the stimulus onset asynchrony (SOA) between cue and target. Although one significant moderating effect of cue ecological validity emerged at 600ms SOA, cue ecological validity was largely not a moderator of the gaze-cueing effect. Overall, this meta-analysis suggests that eye gaze is indeed a powerful social cue that reliably influences the allocation of others' visual attention, but that this effect can be strengthened or reduced as a function of other social perceptual cues such as emotional expression and prior eye contact. Our findings also have implications for our understanding of the roles that task requirements, cue ecological validity, and SOA have on the gaze-cueing effect.

9:30 pm

The face-dependency effect of gaze in working memory: Face context modulates memory performance of gaze

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Gaze is thought to be one of the most important social cues. To enable fluent social interaction, we not only need to read the information behind other's gaze via immediate perception, but also need to store it in the working memory (WM) to continuously keep track of its dynamic changes. However, little is known about how WM retains gaze information. In the current study, we examined whether the storage of gaze information operated independently of other cognitive processes and proposed two competing hypotheses. (1) Given the significance of eye gaze, a dedicated system for memorizing gaze information may exist. If so, gaze direction can be stored in WM independently and insusceptible to its face context (the independent-storage hypothesis). (2) Since gaze is presented in the surrounding of its face context all the time, the gaze-face binding may lead to the expertise of joint processing. If so, the face context would modulate WM performance of gaze direction (the binding-storage hypothesis). Two experiments using the method-of-adjustment were designed to examine the effects of face inversion on gaze direction memory. In Experiment 1, the target gaze was presented within an upright or inverted face context. We asked if there would be a damage to WM performance when

configural face context was disrupted. While in Experiment 2, the probed target was eye region only, and we examined the interference effect of distracting gaze within face context. Results showed that inverted face impaired gaze memory accessibility but not precision (Experiment 1); moreover, upright faces caused more interference on memory accessibility than inverted faces when regarded as distractors (Experiment 2). These findings suggest that gaze direction memory is highly face context-dependent and support the binding-storage hypothesis. Our ability of effectively processing gaze information to some extent benefits from the face context.

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9:45 pm

Psychophysical decoding of 4D dynamic spontaneous facial emotions.

Adelaide L. Burt[1], David P. Crewther[2]; [1]Swinburne University of Technology

Emotion recognition studies have chiefly displayed posed facial expressions as two-dimensional static images, photographs and video-recordings. Recently, facial stimuli have been reproduced as 4D spatial-temporal patterns. Thus, spontaneous, highly-realistic representations of face stimuli are now available where 3D volume and surface models produce dynamic movements across time (BU-4D-S; Zhang et al., 2013; 2014). The aim of the present study is to investigate emotion recognition to 4D spontaneous and dynamic expressions. 13 healthy adult participants performed a 4AFC task to classify facial stimuli in a standard upright or inverted position as either happy, angry, fearful or disgusted expressions. A generalized linear mixed model was conducted on emotion recognition accuracy and response times for fixed factors of emotion and position, with a random factor of individual subjects. The resulting model demonstrated that emotion recognition accuracy for happy expressions was significantly improved compared to the other emotions (83.93%) with a reduction in reaction times at $M \approx 50$ms; disgust (61%; $M = 57$ms, $p < .001$***); anger (32.58%; $M = 74$ms, $p < .001$***); fear (39.14%; $M = 65$ms, $p < .001$***). In the inverted position, no significant differences contributed to the model for reaction time, while only inverted disgust expressions elicited a significant decrease in accuracy. The Facial Action Coding System (FACS; Ekman & Friesen, 1978) demonstrated that the happy expression stimuli present significantly increased activations overall compared to the other emotions, specifically in the mouth region. Based on prior meta-analyses which likewise describe a psychophysical happiness-superiority effect from facial emotions (Calvo et al., 2016), we substantiate that this effect extends to 4D dynamic spontaneous expressions, where superior detection of happy expressions can be linked to increased smiling behaviors or mouth regional activations. We conclude that 4D dynamic and spontaneous facial stimuli are critical to understand how we naturalistically detect emotional expressions.

Acknowledgements: Swinburne University of Technology

Objects and Scenes: Models and mechanisms

Wednesday, May 26, 10:30 am - 12:00 pm EDT, Talk Room 1 Join Zoom Webinar

Moderator: Hans Op de Beeck, University of Leuven

10:30 am

Heuristic Feature Models for Detection of Disrupted Markov Patterns

Dana Pietralla[1] pietralla@wiso.uni-koeln.de, Keiji Ota[2,3], Maria Dal Martello[2,4], Laurence Maloney[2,3]; [1]Psychology, University of Cologne, Germany, [2]Psychology, New York University, [3]Neural Science, New York University, [4]Psicologia Generale, University of Padova

A challenge for the visual system is to go beyond immediately visible patterns to identify the scene processes that generated them. One sees the stripes, one infers the zebra. We asked observers to judge whether each of 100 binary sequences of 20 blue and yellow squares were generated by one of two generators. Each sequence was equally likely to be the outcome of a random generator with probability of repetition 0.5 ("a fair coin") or a two-state Markov generator, with a probability of repetition 0.9, tending to generate long, repeating sequences of yellow or blue. In addition for the sequences generated by the Markov generator, each square in each sequence could be independently disrupted (flipped from blue to yellow or vice versa). There were three experimental conditions with probabilities of disruption 0.1, 0.2, and 0.3, respectively. Each observer received extensive training with both generators and disruption. We first compared human performance to that of an ideal model derived from Bayesian decision theory (BDT). Ratios between the accuracy of observers and that of the BDT model were 0.83, 0.97, and 0.95 in the three conditions. Human observers were markedly suboptimal but (surprisingly) the relative advantage of the Bayesian model decreased with increasing disruption. We then compared human performance to that of several different heuristic feature models (HFMs). Each HFM based its judgment on a specific visual feature of a sequence such as the length of the longest repeating subsequence or the number of subsequences. No HFM performed as well as the Bayesian but some feature models outperformed the median human observer. Two HFMs ("length of longest subsequence" and "total number of repetition") matched the pattern of responses for roughly half the observers. Human performance is better captured by simple heuristic feature models than a model based on Bayesian decision theory.

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10:45 am

Chemogenetic suppression of macaque V4 neurons produces retinotopically specific deficits in downstream IT neural activity patterns and core object recognition behavior

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Distributed activity patterns across multiple brain areas (e.g., V4, IT) enable primates to accurately identify visual objects. To strengthen our inferences about the causal role of underlying brain circuits, it is necessary to develop targeted neural perturbation strategies that enable discrimination amongst competing models. To probe the role of area V4 in core object recognition, we expressed inhibitory DREADDs in neurons within a 5x5 mm subregion of V4 cortex via multiple viral injections (AAV8-hSyn-hM4Di-mCherry; two macaques). To assay for successful neural suppression, we recorded from a multi-electrode array implanted over the transfected V4. We also recorded from multi-electrode arrays in the IT cortex (the primary feedforward target of V4), while simultaneously measuring the monkeys' behavior during object discrimination tasks. We found that systemic (intramuscular) injection of the DREADDs activator (CNO) produced reversible reductions (~20%) in image-evoked V4 responses compared to the control condition (saline injections). Monkeys showed significant behavioral performance deficits upon CNO injections (compared to saline), which were larger when the object position overlapped with the RF estimates of the transfected V4 neurons. This is consistent with

the hypothesis that the suppressed V4 neurons are critical to this behavior. Furthermore, we observed commensurate deficits in the linearly-decoded estimates of object identity from the IT population activity (post-CNO). To model the perturbed brain circuitry, we used a primate brain-mapped artificial neural network (ANN) model (CORnet-S) that supports object recognition. We “lesioned” the model’s corresponding V4 subregion by modifying its weights such that the responses matched a subset of our experimental V4 measurements (post-CNO). Indeed, the lesioned model better predicted the measured (held-out) V4 and IT responses (post-CNO), compared to the model's non-lesioned version, validating our approach. In the future, our approach allows us to discriminate amongst competing mechanistic brain models, while the data provides constraints to guide more accurate alternatives.

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11:00 am

Distinguishing signal strength and spatial structure in fMRI pattern analyses of human primary visual cortex

Fernando M. Ramirez[1] fernando.ramirez@nih.gov, Revsine Cambria[1], Elisha P. Merriam[1]; [1]NIMH, Laboratory of Brain and Cognition

Multivariate pattern analyses are widely used in neuroimaging studies. But it is unclear what these analyses reveal about neural coding. Such approaches often obfuscate the link between neural measurements and the stimulus, greatly limiting their utility. Linear classification, a highly-popular approach, exploits the Euclidean distance among pattern vectors. Our recent theoretical work suggests that information regarding tuning properties is best captured by angular distances, not Euclidean distances. The goal of this experiment was to relate specific aspects of multivariate measurements to parametrically defined dimensions of visual stimuli. We used primary visual cortex as a model system to test the following predictions: (i) Euclidean distances conflate information regarding response amplitude and selectivity, (ii) angular distances best reflect information about selectivity, and (iii) data demeaning—a common preprocessing procedure—invalidates inferences regarding selectivity because it changes angular relationships among pattern vectors. fMRI BOLD activity was measured from 5 participants (7T, 32-channel coil, 1.2x1.2x1.2 mm resolution). Stimuli consisted of Cartesian sinusoidal gratings multiplied by flower-shaped apertures. The orientation of the “petals” was controlled by the phase of the radial frequency (RF) used to generate the aperture. In a fully crossed experimental design, the compound stimulus varied along three dimensions: grating orientation, contrast, and RF-phase, resulting in a total of 96 unique conditions. We found that the Euclidean metric was sensitive to stimulus contrast and relatively insensitive to grating orientation and aperture phase. Angular distances proved sensitive to grating orientation and aperture phase, and robust to changes in stimulus contrast. As predicted, data demeaning led to mischaracterizations of neural tuning. Finally, we used a biologically-inspired image-computable model to provide a theoretic account of these observations. Our results have fundamental implications for the interpretation of MVPA, and inform the development of data analysis strategies that are more readily interpretable in terms of the underlying neurophysiology.

Acknowledgements: This work was supported by the Intramural Research Program of the National Institutes of Health (ZIA-MH-002909)

11:15 am

The effect of object-scene associations upon representational similarity dissociates structured from image-based representations

Stefania Bracci[1,2] stefania.bracci@unitn.it, Jakob Mraz[2], Astrid Zeman[2], Gaëlle Leys[2], Hans Op de Beeck[2]; [1]Center for Mind/Brain Sciences - CIMeC, University of Trento, Rovereto, Italy, [2]Laboratory of Neuro- and Psychophysiology, Department of Neurosciences, KU Leuven, Leuven, 3000, Belgium

We live in a structured world. Some objects are most likely to appear in specific contexts: penguins in ice landscapes and lions in the savannah. How are such statistics of the world represented in the biological and artificial brain? Two main views can be considered: one assuming a structured representation (e.g., separating foreground from background), another centred on image-based computations (e.g., HMAX). Previous experiments that compared biological and artificial neural representations did not distinguish between structured and image-based representations. The effect of this distinction becomes apparent when we consider the problem of statistical regularities. In a structured representation, statistical regularities between identified components can be dissociated from the representation of the components themselves. In an image-based framework, there are no identified components and as such the coding of statistical regularities is more entangled with the representation of the components. Here we test these alternative perspectives with a stimulus set that includes (1) animals (on neutral backgrounds) and (2) their associated scenes, such as ladybugs and leaves. An fMRI event-related experiment (n = 20) confirmed that representations in visual cortex separate objects from their background; no clear representation similarity was observed for associated animals and scenes. In pre-trained DNNs, we found a much stronger entanglement of animals and their associated scenes (e.g., a gorilla and the jungle). This representational entanglement increased towards the last DNN layer. In sum, we show that the nature of representations in an information processing system, being structured or more image-like, has strong consequences for how statistical regularities are coded in such a system. Experiments that probe this nature of representations provide a powerful illustration of the uniqueness of human information processing compared to artificial neural networks.

11:30 am

Unsupervised object learning explains face but not animate category structure in human visual cortex

Ehsan Tousi[1,2] ekahooka@uwo.ca, Marieke Mur[1,2,3]; [1]Brain and Mind Institute, Western University, [2]Department of Psychology, Western University, [3]Department of Computer Science, Western University

Deep convolutional neural networks (DCNNs) are currently the best computational models of human vision. However, DCNNs cannot fully explain the representation of natural object categories in high-level human visual cortex. DCNNs are classically trained to recognize objects using supervised learning, while humans rely heavily on unsupervised learning. Here, we test whether unsupervised learning yields an object representation that more strongly emphasizes natural categories and better explains human brain activity than supervised learning. We trained ResNet50 on the ImageNet database, using both supervised and contrastive unsupervised learning. For both types of learning, we characterized the network's internal representation of 96 real-world object images over the course of 200 training epochs. We fitted a category model to the resulting learning trajectories using ordinary least squares to measure the strength of category clustering for faces, animate objects and inanimate objects. We then compared the networks' learning trajectories and clustering strengths with the object representation in high-level visual cortex, measured with fMRI in human adult observers. We focused our analysis on the deepest convolutional layer and used bootstrap resampling for statistical inference. We found that the unsupervised network better explains the human object representation than the supervised network (FDR corrected $p<0.05$ for 80 percent of epochs). This difference emerges relatively early in training and increases as learning progresses. Better performance of the unsupervised network is partly driven by its ability to discover natural face category structure in the input images. Importantly, both supervised and unsupervised models fall short of predicting category clusters of animate and inanimate objects in the human brain data (FDR corrected $p<0.05$ for all epochs), suggesting that these categories are difficult to learn from static images alone. Our findings suggest that the natural category structure in the human high-level visual cortex may arise from unsupervised learning during development.

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11:45 am

The unreasonable effectiveness of context: Object representations are well predicted by computational models of their natural scene contexts

Caterina Magri[1] cmagri1@jhu.edu, Michael Bonner; [1]Johns Hopkins University

In natural vision, objects are always encountered in a surrounding context, and these contexts can be highly consistent (e.g., most boats appear in aquatic scenes). Previous observations suggest that the human visual system leverages the statistical associations between objects and contexts to facilitate object representation. What are these statistical associations, and how much object information can be inferred from contextual associations alone? Here, we developed a computational approach to model the statistical associations between objects and their image contexts, and we used this approach to determine if contextual information alone can explain key aspects of human object representation. Using large-scale scene datasets, we systematically occluded instances of target objects—leaving only the context intact—and passed the occluded images through an Imagenet-pretrained convolutional neural network (CNN) to obtain average “context-only” representations for a diverse set of object categories. These context-only representations reflect the information that can be learned about an object based solely on its natural image contexts. We also obtained object-only representations using a similar approach (with context occluded). We then examined two common measurements of human object processing: behavioral similarity judgements and fMRI responses to images of isolated objects without contextual backgrounds. We found that both similarity judgements and fMRI responses in visual cortex were well predicted by our context-only representations and that these effects were competitive with those of the object-only representations. The fMRI effects for context-only representations were observed in both object-selective (LO, pFs) and scene-selective (PPA, OPA) regions. These findings are striking because the stimuli in both the behavioral and fMRI experiments were isolated objects without contextual backgrounds, and yet the responses to these objects could be explained by CNN representations of their contexts alone. Together, these findings suggest that object representations in the human brain are shaped by the statistical regularities of their natural image contexts.

Decision Making

Wednesday, May 26, 10:30 am - 12:00 pm EDT, Talk Room 2 **Join Zoom Webinar**

Moderator: Duje Tadin, Rochester

10:30 am

Estimating decision time in perceptual decision making

Ying Lin[1,2], Duje Tadin[1,2]; [1]University of Rochester, [2]Center for Visual Science

Decision-making research almost exclusively relies on reaction times (RT) to estimate decision time. RTs, however, also capture processes not involved in determining decisions (perceptual encoding and motor planning) and necessitate the use of models such as the drift-diffusion model (DDM; Ratcliff & McKoon, 2008) to estimate decision time. Here, we report experiments that support a more direct measure of perceptual decision time: duration threshold, defined as the shortest stimulus presentation duration sufficient to accurately make a perceptual decision. First, we conducted both RT and duration threshold experiments with a widely used task in the perceptual decision-making literature, the random dot motion task (Newsome & Pare, 1988; Roitman & Shadlen, 2002; Hawkins et al., 2015). Twelve participants completed both experiments for six coherence levels (10%-100%). We found that the pattern of duration thresholds over motion coherences closely followed the pattern of DDM-derived decision times and coherence-dependent changes in DDM drift rate. Second, we tested the generalizability of the duration threshold approach using a static orientation discrimination task (N=12) with 8 contrast levels (2.1%-100%). We found that contrast affected performance in a different way than coherence. However, once again, duration thresholds demonstrated a similar pattern as DDM-derived decision times. Lastly, we examined our overall hypothesis in the context of a more complex phenomenon: surround suppression. We used a motion direction discrimination task consisting of two contrasts and three sizes. Participants (N=8) showed elevated duration thresholds for large, high contrast stimuli, replicating previous results of contrast-dependent surround suppression (Tadin et al., 2003). Notably, DDM-derived decision times and not the overall RTs exhibited this contrast-dependent surround suppression. In summary, we show a close correspondence between DDM-derived decision times and duration thresholds in three separate experiments. Evidently, duration thresholds can be used as a direct estimate of perceptual decision time.

10:45 am

Flexible goals require that inflexible perceptual systems produce veridical representations: Implications for realism as revealed by evolutionary simulations

Marlene Berke[1] marlene.berke@yale.edu, Robert Walter-Terrill[1], Julian Jara-Ettinger[1], Brian Scholl[1]; [1]Yale University

How veridical is perception? Rather than representing objects as they actually exist in the world, might perception instead represent objects only in terms of the utility they offer to an observer? Previous work employed evolutionary simulations to show that under certain assumptions, natural selection favors "strict interface" perceptual systems that represent objects exclusively in terms of subjective utility. These simulations showed that interface perceptual systems regularly drive "veridical" systems (those that represent objects in terms of their ground-truth, observer-independent properties) to extinction. This view has fueled considerable debate, but we think that discussions so far have failed to consider the implications of two critical aspects of perception. First, while previous simulations have explored single utility functions, perception must always serve multiple largely-independent goals. (Sometimes when looking at an apple you want to know how appropriate it is for eating, and other times you want to know how appropriate it is for throwing.) Second, perception often operates in an inflexible, automatic manner -- proving 'impenetrable' to shifting higher-level goals. (When your goal shifts from 'eating' to 'throwing', your visual experience does not dramatically transform.) These two points have important implications for the veridicality of perception. In particular, as the need for flexible goals increases, inflexible perceptual systems must become more veridical to meet that need. We support this position with evolutionary simulations showing that as the number of independent utility functions increases, the distinction between 'interface' and 'veridical' perceptual systems dissolves. Under one utility function (or one inflexible goal), our simulations

replicate previous findings that favor interface systems, but under multiple independent utility functions, we find that veridical systems are best able to accommodate multiple goals. Although natural selection evaluates perceptual systems only in terms of fitness, the most fit perceptual systems may nevertheless represent the world as it is.

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11:00 am

What do distinct parietal neural responses for face and motion discrimination tasks reveal about the mechanisms of the decision-making process?

Gouki Okazawa[1] okazawa@nyu.edu, Christina Hatch[1], Allan Mancoo[2], Christian Machens[2], Roozbeh Kiani[1]; [1]New York University, [2]Champalimaud Centre for the Unknown

The firing rate of macaque lateral intraparietal (LIP) neurons encodes the decision variable (DV) for perceptual decisions reported through saccadic eye movements in a random dot direction discrimination task (Shadlen & Newsome, 2001). In circuit models for these decisions, neural ensembles that encode actions compete to form decisions. Consequently, DVs are represented as partially enabled action plans, where ensembles increase their average responses for stronger evidence supporting their preferred actions. As another consequence, DV representation and readout are implemented similarly for different inputs and task contexts when decisions are communicated through the same actions. Here, we examined these assumptions by comparing LIP responses between the motion discrimination task and a novel face discrimination task. Unlike in the motion task, average LIP firing rates during face discrimination were lower for stronger stimuli supporting the preferred saccade target of the recorded neurons, contradicting existing theories. This marked difference in average responses, however, did not indicate different underlying computations between the tasks; population response patterns in both tasks monotonically encoded the DV on a curved manifold in the state space, representing the integration of sensory evidence. This curved manifold rotated and shifted in a task-dependent manner, leading to the opposing trends of average firing rates in the two tasks. These newly discovered properties of LIP activity are not explained by existing circuit models, necessitating development of new models that incorporate task-dependent computations. Furthermore, the curvature of manifold encoding the DV was not limited to LIP; similar curved manifolds were discovered in the lateral and medial frontal cortical regions. This indicates a ubiquitous computational mechanism across the frontoparietal regions that underlies the observed geometry of the DV encoding.

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11:15 am

Prediction of visual attention in embodied real-world tasks

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Understanding how we dynamically distribute our visual attention in real-world environments remains a hard computational problem, due to the complexity of the relationship between natural visual behaviour, task and motor actions. Shifting focus from classical static gaze behaviour experiments, where subjects perform reductionist, head-fixed screen-viewing tasks in front of monitors, to a more dynamic view of real-world tasks requires taking into account ecologically salient features like motion cues, optic flow, and gaze object semantics. To address this, healthy right-handed subjects (n=9, aged 22-28) were given a common neurorehabilitative rubric, and asked to perform a hierarchical, goal-directed task (cooking a predefined meal), whilst wearing synchronised wireless head-mounted eye-tracking glasses and a 66 degree-of-freedom full-body motion tracking suit. We developed three deep autoregressive models for modelling this gaze/body kinematics relationship in PyTorch, using 1) prior gaze alone to predict future gaze direction, 2) a model combining prior gaze and body kinematics as exogenous input to predict gaze, and 3) a linear regression model from body kinematics to gaze. Model training was validated in both open loop with known current gaze position, and closed loop using progressively more predicted values in a sliding window for multi-step-ahead prediction, with leave-one-section-out and leave-one-subject-out cross-validation for in- and cross-subject comparison. Predictive performance averaged 0.08 RMSE (open-loop), and 0.06 RMSE at ~2s (closed-loop). Through our model comparisons

we found that incorporating body dynamics minimised gaze prediction error over longer rollahead timescales of 3s than using just prior gaze data alone. In real-world tasks we can utilise body kinematics to predict gaze on a second-by-second basis, without any visual context. This combination of bottom-up visually-derived saliency and top-down task-centric kinematics-derived saliency may improve further prediction performance and allow us to uncover the mechanisms of interaction.

Acknowledgements: EPSRC

11:30 am

Neural signatures of confidence after the completion of a perceptual decision

Tarryn Balsdon[1], Pascal Mamassian[1], Valentin Wyart[2]; [1]Ecole Normale Superieure & CNRS, [2]Ecole Normale Superieure & INSERM

Feelings of confidence in our perceptual decisions allow us to learn from and communicate the validity of our choices. Confidence should reflect the quantity and quality of evidence used to make perceptual decisions. However, confidence can also benefit from additional information not used by the perceptual system, or can suffer from additional noise. Here we sought to examine the neural computations associated with confidence evaluation and contrast them to those for the processing of the perceptual decision. We used a paradigm in which observers naturally tend to commit to perceptual decisions early, whilst continuing to monitor additional evidence for evaluating their confidence (Balsdon, Wyart, and Mamassian, 2020, Nat Commun). On each trial, observers were presented with a sequence of Gabor patterns and had to choose which orientation category they belonged to. The two categories were defined by overlapping circular Gaussian distributions centred on orthogonal orientations, such that observers must accumulate evidence over multiple uncertain stimuli to make accurate decisions. We traced the neural representation of accumulated evidence for decisions and confidence based on dynamic patterns of electrical brain activity using EEG. While the orientation of each Gabor pattern produced a transient occipital response, the informativeness of each Gabor and the accumulated perceptual evidence were associated to more sustained responses in parietal and frontal regions. The distribution of spectral power overlying motor cortex betrayed early commitments to perceptual decisions, and the neural representation of accumulated evidence used to make decisions was attenuated following these early commitments. However, observers continued to monitor the evidence for making confidence judgments after committing to the perceptual decision. We isolated spatiotemporal clusters of neural activity reflecting accurate confidence evaluation, in particular, in orbitofrontal and superior parietal cortices. Together, these results provide direct empirical evidence of the theoretical dissociation between the computations of perception and confidence.

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11:45 am

Criterion attraction in an external-noise paradigm

Dobromir Rahnev[1]; [1]Georgia Institute of Technology

Humans often have to use different decision criteria in different tasks such as when detecting a mosquito against a white versus a patterned wall. However, it is debated whether people can maintain independent criteria for different tasks. Early work uncovered suboptimal biases when multiple tasks are performed simultaneously, and concluded that in such situations people inadvertently use the same decision criteria across different perceptual tasks. On the other hand, these studies could not measure the criterion location directly and more recent work has questioned whether the same criteria are indeed used across different tasks. To resolve this debate, here we develop a new external noise paradigm that can objectively quantify criterion location across two tasks that optimally require very different criteria. Twenty-eight participants judged which of two overlapping distributions generated full-contrast stimuli of varying orientations. Critically, we included two different experimental conditions. In the Low Variability condition, the two distributions had similar means and low standard deviations (SDs), whereas in the High Variability condition, the distributions had dissimilar means and high SDs. The means and SDs in the two conditions were proportionate so that the tasks were equally difficult. Participants indicated the confidence in their responses and we examined whether the criteria for confidence were independent in the two conditions. We found strong evidence of "criterion attraction" where the criteria across the two conditions moved towards each other but did not become identical. On average, the criteria in each condition shifted by 24% with this effect appearing in every single participant. The criterion attraction led to a large and consistent confidence-accuracy dissociation in the absence of reaction time differences between the conditions. These results unify the seemingly disparate findings in the literature and establish a robust way of inducing dissociations between subjective and objective performance.

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Talk Sessions >

Cortical Hierarchy and Computation

Wednesday, May 26, 1:00 - 2:30 pm EDT, Talk Room 1 Join Zoom Webinar

Moderator: Talia Konkle, Harvard

1:00 pm

Uncovering the circuit mechanisms that shape contextual phenomena with task-optimized recurrent neural networks

Drew Linsley[1] drew_linsley@brown.edu, Lakshmi Govindarajan[1], Thomas Serre[1]; [1]Brown University

Neurons in visual cortex are sensitive to context. Neural responses to stimuli presented within their classical receptive fields (CRFs) are modulated by the presence of other stimuli – in their CRF and their surrounding extra-classical receptive field (eCRF). While these effects have been extensively studied since the inception of visual neuroscience, the circuit mechanisms that shape them and their role in visual perception are not yet understood. We start from the recurrent neural network by Serre et al. (VSS 2020) which can be optimized on visual tasks to implement hierarchical contextual interactions through horizontal (within a layer) and top-down connections (between layers). When optimized for object segmentation, the model rivals human performance and exhibits CRF and eCRF phenomena associated with primate vision, despite having no explicit constraints to do so. With this model, we ask (i) how CRF and eCRF phenomena relate to task performance and (ii) what circuit mechanisms are necessary for their emergence. First, in order to achieve human-level performance along with CRF and eCRF phenomena, a model must learn to implement divisive operations, like shunting inhibition, through its horizontal and top-down connections. Critically, models are only able to learn to do this when they are trained on images with intact semantic-level features. This means that task performance, CRF, and eCRF phenomena are a consequence of horizontal and top-down connections optimized for parsing natural scenes. We validated this finding by developing a procedure for generating contextual stimuli from optimized models. Models that exhibit CRF and eCRF effects can generate stimuli causing lightness- or tilt-illusions for humans. These effects are concomitant with spatially distinct near-excitatory vs. far-inhibitory eCRFs in the model, resembling the long-speculated spatial arrangement of primate visual cortex. Overall, our work demonstrates how recurrent circuitry and visual statistics combine to cause both human-level performance and neural biases.

Acknowledgements: Funding provided by ONR grant #N00014-19-1-2029 and the ANR-3IA Artificial and Natural Intelligence Toulouse Institute. Additional support from the Brown University Carney Institute for Brain Science, Initiative for Computation in Brain and Mind, and Center for Computation and Visualization (CCV).

1:15 pm

A two-stage model of V2 demonstrates efficient higher-order feature representation

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A distinguishing feature of neurons within cortical area V2 is selectivity for higher-order visual features beyond the localized orientation energy conveyed by area V1. Recently physiology has shown that while single units in area V1 respond primarily to the spectral content of a stimulus, single units in V2 are selective for image statistics that distinguish natural images. Despite these observations, a description of how V2 can achieve higher-order feature selectivity from V1 outputs remains elusive. To study this we consider a two-layer linear-nonlinear network mimicking areas V1 and V2. When optimized to detect a subset of higher-order features, fitted model V2-like units perform computations that resemble localized differences over the space of V1 afferents, computing relative spectral energy within and across the V1 tuning dimensions of space, orientation, and scale. Interestingly, we find these model fits bear strong qualitative resemblance to models trained on data collected from single units in primate V2, suggesting that some V2 neurons are ideal for encoding higher-order features of natural images. Interestingly, it is known that cortical neurons, such as those of V1, exhibit sparse (heavy-tailed) response distributions to natural images, a fact that is believed to reflect an efficient image code. Indeed these idealized V2-like units exhibit sparsity, similar to what is seen in model V1 populations. What we show here is that sparseness itself can encode image content: classifiers trained to detect higher-order image features from a population readout of response sparsity are significantly more efficient when using V2-like units than comparable V1-like populations, requiring fewer observations to achieve the same classification accuracy. Thus, we show that differences over V1 afferent activity yield efficient mechanisms for computing higher-order visual features, providing a justification for receptive field structures observed in neurons within primate area V2.

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1:30 pm

Wiring minimization of deep neural networks reveal conditions in which multiple visuotopic areas emerge

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The visual system is characterized by multiple mirrored visuotopic maps, with each repetition corresponding to a different visual area. In this work we explore whether such visuotopic organization can emerge as a result of minimizing the total wire length between neurons connected in a deep hierarchical network. In particular we ask, given N neurons with a given connectivity and a 2-d grid with N locations, how will the neurons be placed on the grid such that the total distance between the connected neurons is minimized? This problem is an NP-hard combinatorial problem which we solve using simulated annealing. We first construct multi-layer feedforward hierarchical networks, and examine how different parameters of the network such as filter size, number of channels, and stride affect the placement of the neurons on the grid. By introducing visual input to the network we can visualize the resulting visuotopic organization on the 2-d grid. Our results show that networks with purely feedforward connectivity typically result in a single visuotopic map, and in certain cases no visuotopic map emerges. However, when we modify the network by introducing lateral connections, with sufficient lateral connectivity among neurons within layers, multiple visuotopic maps emerge, where some connectivity motifs yield mirrored alternations of visuotopic maps–a signature of biological visual system areas. These results demonstrate that different connectivity profiles have different emergent organizations under the minimum wiring hypothesis, and highlight that characterizing the large-scale spatial organizing of tuning properties in a biological system might also provide insights into the underlying connectivity.

1:45 pm

A computational framework for reconstructing mental representations of natural visual concepts

Laurent Caplette[1] laurent.caplette@yale.edu, Nicholas B. Turk-Browne[1]; [1]Yale University

Revealing the features of mental representations is a longstanding goal of cognitive psychology. Although progress has been made in uncovering some low-level representations, there is currently no general framework for investigating representations of high-level visual concepts. We developed a computational method to parametrically map points in the semantic space of category labels to points in the space of visual features, allowing us to reconstruct the representations of many common visual concepts. Specifically, we synthesized "CNN-noise" images from random features in an intermediate layer of a convolutional neural network (CNN) and asked 100 observers to indicate what they saw in each image. We translated their written responses to vectors in a continuous space using a semantic embedding. We then used regressions to uncover how each CNN feature correlated to each dimension in this semantic space. Using this semantic-visual mapping, we could extract the CNN features associated with any concept. From these features, we could then synthesize an image to visualize the concept's prototypical representation. We assessed the quality of these reconstructions (e.g., "grass", "dog", "night") in a separate behavioral validation experiment with 35 observers: 252 of 350 reconstructions were recognized significantly better than chance, suggesting that our method succeeded in visualizing mental representations. We then assessed whether we could predict the semantic content perceived by observers in held-out CNN-noise images: we were able to generate labels closer to the true labels than labels generated by the CNN. Our model also explained similarity judgments of written visual concepts better than the semantic embedding. Finally, it explained unique variance in object representations from high-level visual cortex in fMRI, further suggesting that we captured the structure of mental representations. In conclusion, we developed a computational framework to integrate visual features and semantic dimensions, allowing us to reveal the features and structure of visual representations.

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2:00 pm

Organizational motifs of cortical responses to objects emerge in topographic projections of deep neural networks

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Visual system responses to object images have a systematic topography along the two-dimensional cortex, with selective regions for faces and places located meaningfully within a larger weaker organization of animacy and object size. Interestingly, standard deep convolutional neural networks do not have explicit topography or category-specialized mechanisms, but nonetheless learn feature tuning that has a significant correspondence with neural responses. Here we developed a method to explore the implicit topography within these deep neural network representations, by smoothly mapping the learned feature spaces with a simulated two-dimensional cortex trained using self-organizing principles. We projected a 20x20 grid of map units into the 4096-dimensional feature space of the FC6 layer of object-trained AlexNet, where nearby units on the map have similar tuning. This simulated cortex reflects a smooth spatialized representation of the data manifold in this layer, while still capturing much of the representational geometry of the original deep net layer (r=0.67). Next, we calculated the simulated cortical responses to several localizer image sets. We found a large-scale organization of animate vs inanimate response preferences. Further, clusters of face-selective and place-selective units were evident, even though the object-trained Alexnet wasn't optimized with specialized mechanisms for these categories. As in the human brain, these emergent face regions were within animate preferring zones, while place regions were generally within inanimate zones. Finally, these results were not obtained in randomly initialized projections. Overall, these topographic projections reveal that some of the known large-scale organizational motifs of tuning properties across the human occipitotemporal cortex are implicit in the representational structure learned by deep convolutional neural networks. Broadly, this work provides evidence that the entire object-selective cortex may reflect a smoothly mapped, integrated feature space (Prince & Konkle, 2020), and introduces a new method to link hypothesized representational spaces and spatialized cortical responses.

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2:15 pm

Deep neural network models of visual cortex reveal curvature and real-world size as organizing principles of mid-level representation

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Mid-level visual features directly support an array of behaviors; thus, they may be critical for understanding the functional organization of visual cortex. However, attempts at characterizing mid-level features have been hampered by the difficulty of describing these features in words—they exist in an “ineffable valley” between the describable patterns of low-level vision (e.g., edges) and the commonsense concepts of visual cognition (e.g., objects). Here we developed a novel approach to identify interpretable emergent properties of mid-level representations in deep neural network (DNN) models of visual cortex. Using this approach, we examined DNN models that were fit to scene-evoked fMRI responses in category-selective regions of visual cortex—specifically, scene-selective cortex (sceneDNN) and object-selective cortex (objectDNN). Our method uses a semantically-guided image-occlusion procedure to systematically characterize how DNN activations are driven by the classes of objects within a scene. We examined the relationship between mid-level features and several object properties that have previously been associated with response preferences in visual cortex: curvature, real-world size, animacy, naturalness, and spatial stability. We found that while mid-level features appear complex and difficult to describe at a surface level, large-scale computational analyses can reveal a latent underlying relationship to interpretable object properties. Specifically, we found that the mid-level representations of the sceneDNN support a latent preference for objects that are boxy and large in real-world size. In contrast, mid-level representations of the objectDNN support a complementary preference for objects that are curvy and small in real-world size. These effects were robust to variations of model hyperparameters and were reproducible across different DNN models. Our findings show that curvature and real-world size are emergent organizing principles of mid-level visual representation, and they suggest that differences in mid-level feature tuning may be critical for understanding the

organization of visual cortex into category-selective patches.

Face Perception: Psychophysics

Wednesday, May 26, 1:00 - 2:30 pm EDT, Talk Room 2 Join Zoom Webinar

Moderator: Galit Yovel, Tel Aviv

1:00 pm

Illusory faces are more likely to be perceived as male than female

Sanika Paranjape[1], Susan G. Wardle[1], Jessica Taubert[1], Chris I. Baker[1]; [1]National Institutes of Health

Face pareidolia is the phenomenon of perceiving illusory faces in inanimate objects. Illusory faces have recently been shown to engage similar neural mechanisms to real faces in the human brain (Wardle et al., 2020). To understand whether illusory faces also recruit higher-level mechanisms involved in face evaluation, we ran a series of large-scale behavioral experiments through Amazon Mechanical Turk (N = 2,878). We collected 256 images containing naturally occurring illusory faces in a variety of objects (e.g. potatoes, purses, and peppers), which participants rated on a number of dimensions. We found that illusory faces are readily perceived to have a specific emotional expression and age—most often happy and young. However, our most striking result revealed a strong gender bias, in which illusory faces were much more likely to be perceived as male than female. This male bias was replicated in three separate experiments, and was consistent across participants, gender of the rater, and a wide range of illusory face images presented either in color or grayscale. In control experiments, we found no evidence for a bias in the number of male versus female responses given to carefully matched object images (similar to the illusory face images but without a face) or object names (text labels) that corresponded to the objects in the illusory face images. Thus, this robust male bias for illusory faces could not be explained by pre-existing visual or semantic gender associations with the objects in these examples, and appears to be driven by the perception of the illusory face itself. This bias in the perception of gender for illusory faces indicates that our face evaluation system is broadly-tuned and suggests that the features that are sufficient for face detection are not generally sufficient for the perception of "female".

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1:15 pm

Two faces of holistic face processing

Haiyang Jin[1] haiyang.jin@nyu.edu, Luyan Ji[2,3], Olivia S. Cheung[1], William G. Hayward[3]; [1]Department of Psychology, New York University Abu Dhabi, [2]Department of Psychology, Guangzhou University, [3]Department of Psychology, University of Hong Kong

People tend to process multiple facial parts together as a perceptual gestalt. This holistic face processing is usually measured by three popular paradigms: part-whole task (PW; Tanaka & Farah, 1993), standard composite face task (SCF; Hole, 1994; Rossion, 2013), and complete composite face task (CCF; Richler & Gauthier, 2014). Yet, the specific aspects of holistic processing they are testing remain unclear, since these paradigms do not appear to measure the same construct (e.g., Rezlescu, Susilo, Wilmer, & Caramazza, 2017). We propose that one way these paradigms can be conceptualized is in how they demonstrate the influence of holistic processing: facilitation or interference. In the PW, the same irrelevant facial parts facilitate identification performance for target parts. In the SCF, changing the bottom facial halves interferes with the recognition of aligned top halves. In the CCF, the irrelevant facial halves in congruent and incongruent trials facilitate and interfere with the processing of aligned target halves, respectively. In our study, we inspected both facilitation and interference effects in the CCF, and their dependency on target positions and cueing target probabilities. Thirty-two participants completed the CCF with cues in Experiment 1. In addition to observing the composite face effects, facilitation was observed for both top and bottom facial halves, while interference was only found for the top halves. Another thirty-two participants were recruited in Experiment 2, where the probability of cueing the top (25%/75%) was manipulated. Facilitation was observed for top halves when cueing top probability was high, whereas interference was observed for top halves regardless of cueing top probabilities. These results suggest that the two faces of holistic face processing, facilitation and interference, are not symmetric effects. As such, these findings help explain why the PW (facilitation) and the SCF (interference) tasks may show divergent effects.

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1:30 pm

The power of labels: Conceptual similarity influences face identity decisions

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It is commonly assumed that face identity is determined by visual properties of the face. However, in real life faces are typically learned together with non-facial information that is unique to each identity and can aid identification (e.g., voice, episodic information, semantic information). Here we hypothesized that conceptual similarity between different face images may influence identity decisions beyond their perceptual similarity and objective identity. To test this hypothesis, participants learned pairs of same and different identity faces. All faces were rated for perceptual similarity by an independent group of participants. Conceptual similarity was manipulated by presenting same and different identity faces with the same or different name labels or no labels during learning. During test, participants were presented with the learned face pairs and made similarity decisions as well as identity decisions about each pair of faces. Findings show higher proportion of same identity decisions for faces presented with the same label and lower proportion of same identity decisions for faces presented with different name labels relative to non-labeled faces, indicating a strong effect of conceptual similarity on identity decisions. Performance level that was based only on perceptual similarity was relatively low. However, labels significantly influenced performance level. Labels that were congruent with face identity improved identity decisions, whereas labels that were incongruent with face identity significantly impaired identity decisions. We conclude that perceptual similarity determines identity decisions when no additional information is provided, but may lead to relatively low identification rates. When information about conceptual similarity is provided, it significantly influences identity decisions beyond perceptual similarity and the objective identity of the face. These findings indicate that face identification that is based on perceptual information alone is relatively poor. Conceptual information provides an additional source of information that can improve face identification.

1:45 pm

To Each Their Own: Measuring Familiarity for Face Images

Y. Ivette Colón[1] ycolon@wisc.edu, Emily J. Ward[1]; [1]University of Wisconsin - Madison

Familiarity for never-before-seen faces is a phenomenon tied to both visual perception and personal experience (Lyon, 1996). Can face images be intrinsically familiar? If so, can familiarity be measured consistently? We obtained three measures of familiarity for 100 hyper-realistic, GAN-generated faces, and examined the correspondence in responses among participants and among tasks. Our first task captured memorability (accurate recognition of something previously seen; recognition hit rate, Bainbridge et al., 2016) and familiarity (false recognition of something not previously seen; false alarm rate). However, false alarm-based quantification of familiarity alone is likely more conservative than our typical experiences of familiarity. Therefore, in a second task, we measured familiarity using an untimed forced-choice task in which a new group of participants chose the "more familiar" face in random pairs of faces. The resulting score for each face across participants serves as its familiarity score. Finally, in a third task, we aimed to capture the subjective nature of familiarity for individual faces by having a third group of participants rate faces on a sliding scale between "Not at all familiar" and "Extremely familiar". To establish the reliability among participants in their familiarity judgements, we computed Kendall ranked correlations between image rankings (by familiarity score) for 100 split-halves of the data for each task. We found widespread variability in image rankings (Exp.1 mean tau=0.07, Exp.2=0.01, Exp.3=0.04). We calculated the consistency of participant responses relative to population responses using logistic regression to predict familiarity scores and found varying levels of agreement by participant. Finally, we computed a Kendall correlation for image rankings between tasks and found no significant correlation. The lack of correspondence in responses among participants and tasks suggests that “familiarity” is likely not an intrinsic property of faces and that experimental measures may fail to capture our everyday experience of face familiarity consistently.

Acknowledgements: McPherson Eye Research Institute

2:00 pm

Facial Expressions Reveal Cross-Cultural Variance in Emotion Signaling

Chaona Chen[1] chaona.chen@glasgow.ac.uk, Oliver G. B. Garrod[2], Robin A. A. Ince[2], Philippe G. Schyns[1,2], Rachael E. Jack[1,2]; [1]School of Psychology, University of Glasgow, Scotland, UK, [2]Institute of Neuroscience and Psychology, University of Glasgow, Scotland, UK

Facial expressions of emotion are widely considered to be universal. However, mounting evidence now shows that gold-standard facial expressio¬n stimuli are not recognized across cultures, suggesting cross-cultural variance in facial expression signals. Yet little is known about how facial expressions vary across cultures due to their complexity as dynamic signals. Here, we address this question using a novel data-driven method and an information-theoretic analysis to precisely identify similarities and differences in facial expressions of emotion. First, we modelled dynamic facial expressions of the six classic emotions – happy, surprise, fear, disgust, anger and sad – in two cultures – Western European and East Asian – using reverse correlation. On each experimental trial, we generated a random facial animation composed of a random sub-set of individual face movements called Action Units (AUs), each with a random movement. Participants (120 total; 60 Western European, 31 females, mean age 22 years; 60 East Asian, 24 females mean age 23 years) categorized 2400 such facial animations according to the six emotions, otherwise selecting 'other.' Next, we derived facial expression models of each emotion and for each participant by measuring the statistical relationship between the dynamic AUs on each trial and the participant's responses using Mutual Information (MI, FWER $p < 0.05$). Finally, we used MI to precisely identify the AUs that are culture-specific – e.g., in disgust, Nose Wrinkler (AU9) is Western-specific; Lip Stretcher (AU20) is East Asian-specific – and those that are cross-cultural – e.g., smiling (AU12-6) in happy, wide-open eyes (AU5) and mouth (AU27) in surprise. Our results reveal for the first time the specific cultural variances in facial expressions of emotion, thereby advancing knowledge of human facial expression communication and identifying potential sources of cross-cultural communication breakdown.

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2:15 pm

Using contrast energy to predict access to awareness of emotional faces

Sjoerd Stuit[1] s.m.stuit@uu.nl, Chris Paffen[1], Stefan Van der Stigchel[1]; [1]Utrecht University

Faces with emotional expressions attract and hold visual attention more than neutral expressions. Moreover, emotional faces are thought to have prioritised access to visual awareness. Images of facial expressions differ on many image properties, however, which poses a problem for interpretation. Since any low-level difference between image conditions is a valid candidate to explain any assumed cognitive effects, accounting for these differences between images is crucial. Here we set out to find the image-features of expressive faces that affect their access to awareness. In the current experiment, we presented two face images expressing anger, happiness or a neutral expression to the left and the right of fixation to one eye while dynamic masks were presented to corresponding locations of the other eye. Participants reported which of the two faces was perceived first. Consistent with previous literature, results show that happy expressions have prioritised access to awareness. More importantly, using a combination of machine learning and feature selection methods, we show that utilising contrast energy differences between the two simultaneously presented images allows us to predict which expression will be perceived first. Interestingly, the contrast energy that allows us to predict prioritised access to awareness is not the same as the contrast energy that allows us to decode image category (i.e. anger or happy). To our knowledge, we are the first to show that the race for access to awareness between two images can be predicted using feature selection and machine learning methods. Moreover, we show that the image features that predict relative access to awareness are not the same as those that define the facial expressions used in our task. This suggests that image properties that determine access to awareness are not reflecting the expression of a face.

Poster Session A

Visual Memory: Working, long-term 1

Poster Session A > Visual Memory: Working, long-term 1 > Poster A1

Classification images reveal uniform decay of facial feature information in visual working memory

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Saturday 8:00 am - 10:00 am EDT

Crista Kuuramo[1] (crista.kuuramo@helsinki.fi), Jussi Saarinen[1], Ilmari Kurki[1]; [1]University of Helsinki

For humans, it is crucial to efficiently store facial information in visual working memory (VWM). Here we use psychophysics and a new variant of classification images (CI) to study 1) what are the critical facial features stored in VWM and 2) how these representations change in the course of forgetting. We used the same-different task, where subjects first memorized a face (the memory stimulus), followed by a blank screen lasting either 500 or 4000 milliseconds (the retention time). Then a morphed face (the retention stimulus) was presented, and subjects responded whether the faces were the same or different. In the morphing process for face stimuli, we independently morphed the faces for 12 different face features (e.g. eyes, nose, mouth) towards the mean face, which was an average morph over all face stimuli. Retention stimuli morphs were generated by adding random jitter for each facial feature towards the mean face, making them locally less characteristic. In “same” trials low-variance jitter was added to the retention stimulus. In “different” trials we sampled the jitter from a high-variance distribution, making the retention stimulus appear on average more different from the memory stimulus. Then we estimated decision weights for each facial feature with CIs. The weights show how strongly information in each feature contribute to memory-based decisions. CIs were estimated using a regression model, where the difference in randomized feature jitter values in the two stimuli predicted subjects’ responses. Thus, these CI weights indicate how much information subjects extracted from each facial feature in the memory task. The CIs revealed large weights for eyes and mouth in both retention times. However, CI weights were uniformly smaller in the longer retention time: forgetting seems not to change the set of facial features stored in memory representations. Instead, forgetting may cause uniform decay in all features.

Acknowledgements: This research is supported by Jenny and Antti Wihuri Foundation.

Poster Session A > Visual Memory: Working, long-term 1 > Poster A2

Using Visual Memory Schemas for Modulation of Image Memorability

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Saturday 8:00 am - 10:00 am EDT

Cameron Kyle-Davidson[1] (ckd505@york.ac.uk), Adrian G. Bors[2], Sophie Skelton[3], Karla K. Evans[4]; [1]University of York

Image memorability can be defined as a combination of intrinsic characteristics of the image itself and the degree of its correspondence to the human observer’s knowledge structure of the world. Understanding and extracting the image features that contribute to memorability is still a challenge. Advances in computational techniques have allowed for interpreting what makes an image memorable, in addition to predicting the memorability of a given image. Visual memory schemas (VMS) are one such operationalization that defines image memorability as two-dimensional memorability maps that capture the most memorable regions of the scene, predicting with a high degree of consistency human observer’s memory for the same images. These maps correlate with mental schemas employed by humans to encode visual memories. Here we ask whether it is possible not only to predict but also modulate human memory with artificially generated images. We developed a computational approach based on deep learning models for estimating and enforcing the VMS maps when generating realistic high-resolution images. The generated images are high and low memorability pairs of images, where the only difference between images is a variation in the continuum of VMS-defined memorability. We then conducted a recognition memory experiment, where human observers are shown sequences of artificially generated images and are asked to indicate if they have seen a given image before. The observers show a significantly superior memory for the highly memorable images compared to poorly memorable images, for VMS-defined memorability and hit rate. Raising memorability of an image also increased the chance of it being falsely remembered, mirroring findings from visual memory schema experiments that employ real images. Implementing and testing a

construct from cognitive science allows us to generate realistic images whose memorability we can manipulate at will as well as providing a tool for further study of mental schemas in humans.

Poster Session A > Visual Memory: Working, long-term 1 > Poster A3

Expectations about the number of task-relevant objects gate attentional access to working memory

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Saturday 8:00 am - 10:00 am EDT

Alon Zivony[1] (alonzivony@gmail.com), Martin Eimer[1]; [1]Birkbeck, University of London

In dynamic environments, encoding information in working memory (WM) depends on allocating attention to the relevant object at the right time. In rapid serial visual presentation (RSVP) tasks, failures in attentional selectivity are frequently observed when a target is followed by a potentially reportable distractor. However, in tasks with two targets, accuracy for both targets is typically high when they are presented in immediate succession (lag-1 sparing). To account for this disparity, we tested whether expectations about the number of targets in RSVP streams gates their access to WM. Colored target digits were embedded among grey letters and digits in two lateralized RSVP streams. The first target was followed either by a grey digit, or a second target (another colored digit). To manipulate expectations, the ratio of one-target and two-target trials (75%-25% or vice versa) was varied between blocks. Participants were much more likely to report seeing two targets when two targets were expected, even on trials where only a single target was present. To rule out response bias, we measured ERP markers of attentional selection (N2pc) and WM storage (CDA) in a second experiment. Both components were larger when two targets were expected, regardless of the actual number of targets, demonstrating that expectations modulated attentional selection as well as the number of items encoded in WM. In a third experiment, participants always provided two guesses about the targets’ identity, and blocks with 100% one-target trials were followed by blocks with 100% two-target trials, or vice versa. The number of reported items varied with expectations only for observers who started with one-target blocks, plausibly reflecting the strategic advantage of maintaining an expectation for two targets in this task. Together, these findings reveal that attentional selectivity and WM encoding is modulated by expectations about the amount of task-relevant information.

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Poster Session A > Visual Memory: Working, long-term 1 > Poster A4

Here it comes: Working memory is effectively 'flushed' even just by anticipation of an impending visual event boundary

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Though visual input arrives in a continuous stream, our perceptual experiences unfold as a sequence of discrete events. This form of visual event segmentation has important consequences for our mental lives. For example, memory is disrupted not only by elapsed time, but also by crossing an event boundary. Even an activity as simple as walking through a doorway can effectively 'flush' memory (just as one might empty a cache in a computer program), perhaps because this is when the visual statistics of our local environments tend to change most dramatically -- and it may be downright maladaptive to hold on to now-obsolete information. But just when does this 'flushing' occur? At the very moment we cross the boundary? When we encounter new post-boundary information? Here we provide what may be a surprising answer: even just the *anticipation* of an impending event boundary is sufficient to flush memory. Observers viewed an immersive 3D animation in which they walked down a long virtual room. Before their virtual walk, they saw a list of pseudo-words, their recognition memory for which was then tested immediately after the walk ended. Two of the conditions were inspired by past work: during their walk, some observers passed through a doorway, while others traversed the identical path through a room that had no such event boundary. Critically, we also tested a third condition, in which memory was probed just before the observers would have crossed through the doorway -- while carefully equating for elapsed time by manipulating the doorway's location. Relative to the baseline no-doorway condition, we observed reliable memory disruptions in *both* the 'doorway' and 'anticipation' conditions -- and additional control experiments confirmed that this was due to anticipation of the event boundary (and not just surprise). Visual processing thus *proactively* flushes memory by anticipating future events.

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Random values from uncertainty intervals are as informative as point estimates in visual working memory

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Human actions rely on memory to guide behavior. Memory is inherently noisy, thus a single memory representation (e.g., a color hue) accords to several nearby values in feature space. To translate memory into concrete behavior often a point estimate has to be drawn from this set of possible values. Current accounts of visual working memory assume that this point decision is based on a maximum-likelihood estimate derived from a bell-shaped probability distribution of possible output values. Here we tested an alternative model of visual working memory. Namely, that memory-informed behavior results from a random choice within an equal-probability set of neighboring exemplars (e.g., a range of similar colors). Fifty-eight participants conducted a standard color working memory task (Zhang & Luck, 2008) with variable set size (1, 2, 4) and one probed item per trial. In half of the trials, participants responded with a standard point estimate on a color wheel. In the other half, participants indicated an interval (i.e., consideration set) in which they considered the target color to be. Response conditions were randomly interleaved and unknown to participants during encoding and delay but cued only prior to report. We calculated the accuracy (mean absolute deviation) of the point estimate responses and compared them to the accuracy of simulated point estimates drawn randomly from each interval, thereby simulating the equal-probability model. Assuming the maximum-likelihood model we would expect higher accuracy for point estimates. In contrast, Bayesian analyses provided evidence that point estimates did not contain more accurate information about the memorized colors than randomly drawn values from the consideration sets. Our results challenge the view of memory representations as continuously graded exemplar-based probability distributions but suggest to conceive memory as rather discrete sets of informationally equivalent response options.

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Reliability of Visual Access: Modeling the trade-off between internal storage in visual working memory and external sampling

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We use visual working memory to temporarily store visual information about our environment. However, our environment is mostly visually static and as such, memory can often be ‘offloaded’ onto the environment. As a result, there is a trade-off between choosing to internally store information or to externally sample it. In the present study, we explored how this trade-off changes as reliability of access to the environment changes, by submitting participants to a copying task, in which they copied a layout of stimuli on the left side of a computer screen to the right side of the screen. The example layout intermittently disappeared throughout a trial, the timing of which was varied across conditions. As the example layout disappeared for greater amounts of time, participants sampled it less often (and thus memorised more items at once) than in the baseline condition, in which the example was always visible. We then designed and ran a computational cognitive model. This model explored different combinations of strategies regarding the number of stimuli it attempted to remember with each gaze toward the example layout, and regarding how often a stimulus was rehearsed in memory after its first encoding. We then compared human data and model data on three outcome variables: (1) the number of crossings from the right side of the screen to the example layout on the left side; (2) the completion time of trials; and (3) the number of fixations per second. We present a model which approximates human data fairly accurately, and show that incorporating specific memory strategies caused models to fit more strongly than when they were disregarded. Our findings reveal a clear shift in the usage of visual working memory when reliability of visual access changes, and validate the storage/sampling trade-off in environments with varying reliability of visual access.

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The format of visual working memory representations

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Working memory (WM) enables us to maintain and manipulate information in the absence of an external stimulus. The contents of visual WM can be decoded from the spatial patterns of neural activity during memory delays across a widely distributed network of brain regions (Sreenivasan & D'Esposito, 2019). However, the nature of what is being represented by these patterns remains unclear and could even vary across the visual hierarchy. For instance, the direction of dot motion might be maintained by neurons in visual cortex with directional motion selectivity. Perhaps at the same time, abstract representations of motion direction (e.g., imagined vector) might be maintained by neurons in higher cortical areas, which lack motion direction tuning. To test this hypothesis, we examined whether features with a similar nature, such as orientation and motion direction, share a common neural representation during WM using cross-modality decoding. We measured fMRI activity in participants maintaining the orientation of a gabor or the motion direction of a random dot kinematogram over a 12s delay period of a delayed estimation WM task. Similar to previous studies, the contents of WM could be decoded from the patterns of activity in several retinotopically defined visual field maps. Critically however, we find that in some maps that a decoder trained on one type of target stimulus (e.g., gabor orientation) can successfully decode the other type of target stimulus (e.g., dot motion direction), indicating that the low-level visual features do not constitute the format of the WM representation. Moreover, cross-modality decoding accuracy was lower when training and testing on the stimulus presentation period, indicating that the representation shared across modalities is specific to WM. In conclusion, the common representational format across memory for orientation and motion direction suggests that high-dimensional perceptual information is condensed into low-dimensional representation for WM.

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The Item-Specific Proportion Congruency Effect is Contaminated by Short-Term Repetition Priming

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The item-specific proportion congruency (ISPC) effect constitutes the phenomenon that Stroop effects are reduced when incongruent items belong to a mostly-incongruent (MI) than a mostly-congruent (MC) grouping. While the ISPC effect is purported to reflect associations formed in long-term memory, the assigned proportion manipulation entails that stimulus repetitions vary as a function of the MC and MI conditions, leaving open the possibility that a short-term repetition priming process may work to enlarge the Stroop effect in the MC relative to the MI group. In the present study we investigated whether the ISPC effect reflected contributions from separate long-term associative learning and short-term repetition priming processes. To do so, the magnitude of the ISPC effect was compared when stimulus repetitions were systematically present and absent across the experimental session. While we observed that the ISPC effect was robust across groups, it was revealed that removing stimulus repetitions significantly attenuated the effect. Additionally, it was revealed that stimulus repetitions had a profound impact on performance, and sequential congruency (i.e., congruent-to-congruent and incongruent-to-incongruent inter-trial repetitions) had none, suggesting that this repetition priming process depended on the repetition of stimulus features. Overall, the present study indicates the typical ISPC effect reflects contributions from both short and long-term memory processes.

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Visual working memory for objects in scenes in younger and older adults: Insights from pupillometry

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Pupillary responses are known to differentiate younger and older adults (e.g., senile miosis) and have been recently linked to successful recognition in memory tasks. However, it is yet to be understood whether age-related changes in pupil dilation would show differential patterns during recognition memory tasks. In the present change-detection study, younger and healthy older adults viewed 192 original and modified versions of indoor photographs to determine whether a change had (or not) occurred with equal probability (i.e., 50% of the trials). In the modified version of the image, a change could be made to the identity of one of the objects in the scene (e.g., a toothbrush became a torchlight), to its location (e.g., a toothbrush moved from left to right), or to both features (e.g., a toothbrush moved and became a torchlight). On normalised (z-scored) pupil dilation collected during the recognition phase while the changed target object was fixated, we found that pupil size was significantly smaller in trials in which participants correctly than incorrectly detected a change. Crucially, this difference was greater for the younger adults than for the older adults. Further analyses on correct trials also revealed a significant interaction between group and type of change: older adults had smaller dilation when the target changed in identity compared to when it changed in location, whereas the opposite effect was observed in younger adults. We argue that the greater effort to identify a change in an object's location compared to a change in identity may reflect the reduced useful field of view in older adults. Our results align with previous evidence of a negative relationship between pupil size and recognition memory and suggest that such pupillometry can help identifying the use of compensatory strategies in older adults during visual working memory tasks.

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Location Encoding in Visual Working Memory is not Completely Automatic

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Spatial information is often thought to hold a privileged role in visual working memory although it is unclear whether this always entails complete encoding of all available location information. In this study, we investigated to what extent spatial information about a visual memorandum is automatically encoded into VWM. Using a delayed estimation task, we directly assessed the quality of incidentally encoded location memory (experiment 1) and orientation memory (experiment 2). A surprise trial was introduced for either feature at a point when only the item's color had been task relevant. This was followed by control trials to assess the memory quality when location or orientation had become task relevant along with color. We found the surprise trial performance to be significantly worse than the first control trial for both location and orientation, rejecting the notion that location encoding is completely automatic. Importantly, however, there was measurable location information on the surprise trial of experiment 1 while the surprise orientation report in experiment 2 was indifferentiable from a uniform distribution. Consistent with this difference, color memory precision was reduced after the surprise trial in both experiments, but less evidently so in the location-report experiment. We thus have convergent evidence that some location information was being encoded even when it was task irrelevant, but making the requirement of location report explicit induced the encoding of even more precise location information. All results were accompanied by data from pre-registered replication experiments. We reconciled our findings with previous studies suggesting automatic location encoding by emphasizing that automatic processes might be involved in encoding to various extents. Our study highlights the importance of acknowledging that the automaticity of memory encoding processes is not necessarily all-or-nothing and can exist along a graded scale.

Acknowledgements: This work was performed with the support of NSF grant 1734220 awarded to B. W..

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Metrical properties of spatial and temporal reference frames in visual working memory

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Space and time structure our visual experience, yet little is known about the role of temporal aspects for visual working memory (VWM). We have recently shown that both spatial and temporal properties are incidentally encoded along with to-be-remembered information, providing reference frames for storage and retrieval. In our prior work, we used rich spatiotemporal contexts, as they might be encountered in natural environments: Memory contents could be differentiated based on (a) absolute spatial/temporal coordinates, (b) relative spatial/temporal coordinates, or (c) their position in a categorical spatial/temporal order. The drawback of this approach is that it leaves open the question of specifically which spatiotemporal properties are critical. In a series of experiments, we used a colour change-detection task to test each of these possibilities by transforming spatial and/or temporal structures of item presentation at retrieval relative to encoding. More specifically, spatial and/or temporal coordinates were (a) multiplied by a constant factor, expanding or shrinking the entire configuration (global change), (b) multiplied by different factors, changing relative inter-item distances (relational change), or (c) switched, changing the order of items in a spatial or temporal sequence (ordinal change). Such transformations of the external reference frame at retrieval should only affect performance if the metric of the internal reference frame in VWM is not invariant to this type of transformation. We found that ordinal and relational changes of either the spatial or temporal structure impaired performance, whereas global changes had no effect. Thus, reference frames appear to be established by inter-item relations – including relative distances between items as well as their order – rather than absolute positions in space or time. These results corroborate and extend previous findings for the spatial domain, and highlight functional similarities between the spatial and temporal dimensions by revealing the same metrical properties for temporal reference frames.

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Visual Memory: Encoding

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Binding continuous features in working memory with plastic attractors

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Visual working memory (WM) allows us to maintain arbitrary combinations of information bound into novel objects. The information comes from continuous feature spaces, resulting in limited precision and graded biases. WM theories are divided into two camps: slot-like models that include feature binding, and continuous attractor models that predict graded biases. No current models explicitly account for both these aspects of human WM. A recent computational model of WM models binding in a biologically plausible network. Rapid synaptic plasticity supports the formation of discrete-feature bindings and their maintenance in WM background, whereas persistent activity forms the WM foreground by holding a single representation in a focused state. In this study, we extend this model to represent continuous feature spaces. Bindings of multiple continuous features are stored as “plastic attractors” in flexibly-coding conjunction neurons and the network produces continuous report via pattern completion. Analysis of model activity shows that recall errors stem from competition between representations. Depending on the particular way the competition resolves in individual trials, simulated errors can be assigned to different error sources: imprecision of target representation, swap errors and random responses. The model accounts for a range of WM effects including the effect of set size on precision and misbinding, and serial order effects. It also produces biases generated by interference when multiple items are maintained concurrently and generates a novel prediction: similarity along the to-be-recalled dimension and along the probe-feature dimension should have different effects on the pattern of errors. Furthermore, continuous, plastic changes in conjunction neuron selectivity can account for serial biases, where recall is biased towards items encountered on previous trials. In summary, the continuous binding model can capture a variety of WM effects that other theories cannot, and shows that transient flexible coding can support binding of continuous features.

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Binding information to discrete objects improves retention in working memory

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Spatial information uniquely influences working memory. In many cases, task-irrelevant spatial information influences memory while other kinds of task-irrelevant information (e.g., color, auditory tones) do not. But how does this spatial influence occur? What spatial cues matter? Here, we ask whether information bound to discrete objects is better remembered than information bound to those same locations but over a continuous space. In our baseline task, participants played a memory game in which they had to remember sequences of shapes appearing every other second. Sequences were made up of 5-7 shapes (three unique ones: circle, diamond, and pentagon) that could appear in one of four locations (four separate quadrants) and in one of four colors. Participants were instructed to remember what shapes they saw and in what order. On some trials, spatial information was structured so that repeated shapes were always in the same location (but color was randomized). On other trials, color information was structured the same way (but location randomized). Critically, all four locations were marked by discrete squares in which the shapes could appear. In this task, participants better remembered the shape sequences on space-structured trials. In a follow-up experiment, we simply removed the discrete squares marking where shapes could appear. In this case, participants did not exhibit the same memory boost in the space-structured trials. We also tested whether this effect depends on encoding or retrieval by initially presenting the discrete black squares but removing them at test. Here, there was a marginal effect of spatial structure. Combined, these results suggest that binding information to discrete objects in specific locations as opposed to continuous space — even when that spatial information is task irrelevant — benefits memory. Working memory, like attention, may therefore rely in part on object-based processes.

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Building a comprehensive model of visual memory from images and individuals

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In our daily lives, we only remember a fraction of what we see. Memory failures can arise from factors including attentional lapses and poor item memorability. However, most models of human memory disregard both an individual's attentional state and an image's memorability. In this study, we consider these image and individual-specific influences on memory simultaneously to build a model of visual memory. To this end, we analyzed data from two experiments (N=55) that used response time to index attentional state during a visual attention task (with trial-unique scene stimuli) and measured subsequent image recognition. We then collected data from participants (N=722) performing a continuous recognition task on Amazon Mechanical Turk to characterize the memorability of each of these 1100 scene images. Memorability was operationalized as the online participants' average memory performance as performance was highly consistent across individuals. We next used mixed-effects models to predict subsequent recognition memory in the two attention experiments. Specifically, we predicted recognition memory from each image's memorability score (which varied across images but was constant across individuals) or the attentional state at encoding (which varied across both images and individuals). These models revealed that both image memorability and individual attentional state explain significant variance in subsequent image memory. Furthermore, a joint model including both memorability and attentional state predicted subsequent memory better than models based on either factor alone and demonstrated that memorability and attention explain unique variance in subsequent memory. Thus, building models based on both individual and image-specific factors allows for directed forecasting of what we remember.

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Discounting the Effect of Memory on Repeated Measures of Beauty Judgment

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The intrinsic variance of beauty judgment is key to modeling beauty ratings. However, in repeated measures of beauty, observers surely make use of what they remember. To test how memory contributes to repeated beauty ratings, we asked participants to rate 75 arbitrarily named images (e.g., Fred). Initially, participants rated (1 to 7) how much beauty they felt from looking at a named image. Then participants completed two conditions. In the memory condition, participants saw only the name of an image and were asked to remember the image corresponding to that name and rate how much beauty they felt. In the repeat condition, they once again rated how much beauty they felt from looking at a named image. Lastly, in a memory check, participants tried to select which image was associated with a name. Only considering the correctly remembered trials (60%), we calculated the distribution of the differences between the initial beauty rating and that from either the memory condition or the repeat condition. The variance for the memory condition was more than double that of the repeat condition. Likewise, the initial beauty ratings predicted 84% of the variance in the repeat ratings but only 30% of the variance in the memory ratings. Cue combination studies report that observers typically combine cues by the optimal Bayesian rule: The combined reliability is the sum of the separate reliabilities for each cue, where reliability is one over variance. Assuming optimal combination of memory and immediate-perception judgment, we can discount the contribution of memory to estimate the variance of the immediate-perception judgment. Thus, in our paradigm the 0.83 variance of the repeated beauty rating corresponds to a 0.97 immediate-perception judgment variance (without memory). Overall, since there also was no significant difference in means, our results indicate that memory contributes little to repeated beauty ratings.

Acknowledgements: NIH Core Grant P30 EY013079

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Does average size of an ensemble bias individual size representations during perception or working memory retention?

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When processing multiple visual items, the representation of individual items can be constrained by properties of the group. Prior studies have reported such ensemble bias, where memory for the size of an individual item is biased toward the average size of the group (Brady & Alvarez, 2011). However, it is unknown whether ensemble statistics influence individual representations during perception or over the course of memory retention. The current study aimed to dissociate perceptual-based and memory-based bias using a size comparison task. In the memory-bias condition (similar to prior designs), an array of 4 differently sized circles was presented briefly, and participants were instructed to remember the size of the one white-outlined target circle and ignore the three black-outlined nontarget circles. After a 2 second delay, another single white-outlined probe circle was presented at the center of the display. Participants judged whether the first (target) or second (probe) circle was larger. We expected to see the ensemble bias, where the size of the initial target circle was biased toward the average size of the array, resulting in a shift in the psychometric curve. In the perceptual-bias condition, the stimuli presentation order was reversed. The single probe circle was presented first, and the 4-circle array containing the target circle was presented after the delay. Because participants had to respond immediately after the target array presentation, any bias found in the perceptual-bias condition should indicate interaction at perception rather than bias developing over the WM retention period. In subsequent experiments, we further manipulated the length of the WM interval in the memory-bias condition. We found comparable bias toward the average ensemble size in both the memory-bias and perceptual-bias conditions. This result provides novel evidence of interaction between individual and group-level ensemble representations during the perceptual encoding stage.

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EEG signals represent updated memory representations in working memory

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Visual short-term memory (VSTM) creates continuity of representations over time. Working memory, in addition, gives us access to these representations to manipulate or update them. Visual representations stored in VSTM have been successfully reconstructed from measurements of neural activity. However, it is unclear whether the updated state of a remembered item is reflected in these neural representations. To ask this question, we measured alpha-band oscillations (8-12Hz), associated with visual attention, and sustained EEG potentials (<6Hz), associated with visual short-term memory maintenance, while participants remembered and updated a sinusoid gabor in visual short-term memory. In the task, participants were asked to mentally rotate a grating based on a color cue that indicated whether participants should rotate the remembered item 1) clockwise, 2) counter-clockwise, or 3) not at all. We found that reconstructions from sustained EEG (< 6 Hz) reflected updated representations with higher fidelity while alpha-band frequency (8-12Hz) computed broad scope of reconstructions including initial sensory representations. These results suggest that neural signal carries not only the sensory information but also manipulated mnemonic representations.

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Evolving visual representations from noise

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Seeing involves not only the light that reaches our retinae, but also visual memories and expectations. When searching for our favourite mug, we hold its appearance in mind. When talking to a friend over the phone, we picture their facial expressions. Talented artists can even paint detailed visual scenes from memory. The content of such mental representations is of great interest in perceptual and cognitive neuroscience, yet is challenging to measure experimentally (alas, too few of our participants are talented artists!). One previously-proposed approach is reverse correlation. Participants are asked to report whether they see a signal—e.g., the letter "s"—in pure noise. Over enough trials, some random noise samples will happen to resemble the signal the participant has in mind. Averaging over all trials in which a participant spuriously detected a signal provides a "classification image" — a visualisation of their representation of the letter. One major drawback of reverse correlation is that it requires tens of thousands of trials to obtain even coarse impressions of mental images. Perhaps more importantly, reverse correlation cannot recover multiple concurrent templates. If a participant imagined both print and cursive instances of the letter "s", the recovered classification image would be a jumble of both. We address these issues using an evolutionary algorithm approach. We generate image populations by crossbreeding noise. On each trial, participants are shown multiple alternative images drawn from these populations. Across generations, only those images in which participants detect a signal are kept for further breeding. In both simulation and experiments with human participants, we demonstrate that this method converges faster than standard reverse correlation, can recover multiple internal representations of a signal, and can even provide access to the mental representation of illusory visual percepts. Our approach thus provides an efficient, data-driven way to access complex mental representations.

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How do humans process numerosity

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Numerical cognition is widespread among animal species (Brannon & Park, 2015) and present from birth in humans (Izard, Sann, Spelke, & Streri, 2009). Laboratory studies show that longer stimulus duration improves numerical discrimination accuracy (Inglis & Gilmore, 2013; Wood & Spelke, 2005). Inglis & Gilmore (2013) suggested that longer durations allow subjects to resample the stimulus image multiple times, resulting in a more accurate final estimate. The current study tested this "multiple sampling" hypothesis alongside two competing hypotheses ("sequential enumeration", "longer processing time") to determine why stimulus duration relates to accuracy. Adult subjects (N=14 and 15, in E1 and E2, respectively) completed a fully within-comparison, 2AFC task in which they judged which of two arrays had more dots; accuracy was the dependent measure. Display time was kept brief to prevent counting. Experiment 1 found higher accuracy in the 500ms stimulus condition than the 100ms condition (M_{100ms}=0.57, M_{500ms}=0.65, $F(1,13)=30.63$, $p<.001$). Although post hoc Helmert comparison revealed significant difference between extra small

group and other three larger groups (Mextra_small=0.64, Mlater=0.60, F(1,13)=49.21, p<.001), no difference was found between three larger set size groups (all Fs<3.00, all ps>0.008), suggesting that items were not enumerated sequentially. Data from Experiment 2 extended these findings. When stimulus duration was held constant at 100ms, adding a 400ms delay between stimulus offset and mask onset improved accuracy (M100+0msDelay=0.61, M100+400msDelay=0.64, F(1,13)=19.84, p=.001). There was no difference in accuracy between the 500ms stimulus duration condition (E1) and the 100ms duration + 400ms mask delay condition (E2) (F(1,28)=0.16, p=.70, >.025), indicating that overall processing time rather than stimulus duration per se improves accuracy. This is contrary to the multiple sampling hypothesis forwarded by Inglis & Gilmore, but we note that we cannot exclude the possibility that sampling continues in iconic memory. These findings provide insights into the processes underlying number representation.

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Serial dependence in visual working memory: cognitive and neuronal mechanisms

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The processing of a visual object can be systematically biased towards an object that was processed several seconds ago. This phenomenon, called serial dependence, has been thought to promote an object’s stability by compensating for small changes of its appear-ance over time. Up until now, it has been debated whether this attractive bias occurs at perceptual or post-perceptual levels of the processing hierarchy. To address this issue, we recorded neuronal activity using MEG while participants remembered motion directions of two sequentially presented red and green items. After a delay, a colored retro-cue indicated the item whose motion direction participants had to report. We observed that the currently reported motion direction was biased toward the item retro-cued on the previous trial. This bias was present when the current and the previous item's motion directions were similar to each other and further increased when items shared the same color. This replicated our recent results (Fischer et al., 2020). Using an inverted encoding model, we could reconstruct the motion direction from the MEG signal of both items in the current trial. The reconstruction was perfectly aligned to the actual motion direction at time-points when the corresponding item was presented and memorized. Our preliminary analyses also showed that after the retro-cue, the reconstructed signal was slightly shifted towards the direction of the item retro-cued in the previous trial. This suggests that serial dependence operates when an item is accessed in working memory rather than when it is perceived or memorized.

Acknowledgements: This study was supported by the German Academic Scholarship Foundation (PhD Scholarship awarded to C.F.)

Poster Session A > Visual Memory: Encoding > Poster A22

Temporal integration of feature probability distributions in visual working memory

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Saturday 8:00 am - 10:00 am EDT

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Visual memory has remarkable effects on human search behavior. In particular, when target features are repeated, search efficiency increases. Similar effects are also found for repeating distractors. Conversely, when a distractor feature and target feature reverse their roles, search times are slowed down. Recent studies have revealed that the visual system is not only sensitive to distractor features per se, but the actual distractor feature probabilities. Changes in search times were determined not only by whether that particular feature characteristic was a distractor but also the frequency of that distractor feature over consecutive trials: Most probable distractors produced the strongest role reversal, while less probable distractors produced weaker role reversals. These search displays involved many distractor exemplars on each trial, but whether observers can learn distributions where only a single exemplar from a distribution is presented on each trial remains unknown. Here, we investigated whether target probability distributions can be encoded in working memory. Over blocks of trials (144 trials per block) observers searched for an oddly-colored target that was

drawn from either a Gaussian or uniform distribution. Not only was search influenced by the repetition of a target feature but more interestingly also by the probability of that feature within the block. The same targets, coming from the extremes of the two distributions were found significantly slower when distractors were drawn from a Gaussian distribution than from a uniform distribution indicating that observers were sensitive to the target probability. In a subsequent experiment we replicated the effect using binned distributions and moreover discovered the limitations of target distribution encoding by using bimodal target distributions. Our results demonstrate detailed internal representations of target probability distributions in working memory and the visual system's ability to integrate single exemplars into probability distributions over surprisingly long trial sequences.

Poster Session A > Visual Memory: Encoding > Poster A23

The multiple encoding benefit: contributions from the number of encoding opportunities amplifies benefits from the length of encoding duration in visual long-term memory

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Saturday 8:00 am - 10:00 am EDT

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Despite the virtually unlimited capacity of visual long-term memory (VLTM) (e.g., Brady et al., 2008), not all visual information that we wish to remember gets encoded into VLTM. One robust way to enhance VLTM encoding is to encode the visual information over multiple opportunities; known as the multiple encoding benefit (MEB). However, it is unclear whether it is the number of encoding opportunities or the total encoding duration that underlies the MEB, because as the number of encoding opportunities increases, so does the encoding duration. Thus, we dissociated the contributions of the number of encoding opportunities and the encoding duration and measured their impacts on objective memory recall precision as well as subjective memory recall confidence. Specifically, we had participants encode a series of 360 pictures of real-world objects presented in a solid colour drawn from a 360° colour wheel (Brady et al., 2013). During the serial presentations, baseline pictures were presented once for 500ms, while some were presented once for 1000ms, and other pictures were presented twice for 500ms each with variable lags between the two presentations. Here we found that while elongating encoding duration benefited both objective and subjective memory recall performance, there was also a unique benefit of additional encoding opportunities on both measures of memory performance. Importantly, the magnitude of this additional benefit amplified as a function of the lag between the two encoding opportunities. Therefore, the MEB is not just due to the increase in total encoding duration but is driven by the increase in the encoding opportunities.

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Poster Session A > Visual Memory: Encoding > Poster A24

The Visual and Semantic Features that Predict Object Memory

View Poster | Visit me in Gather.Town Osprey Room on Saturday 8:00 am - 10:00 am EDT

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Humans have a remarkable fidelity for visual long-term memory. Much of the work on long-term memory has focused on processes associated with successful encoding and retrieval. However, more recent work on visual object recognition has developed a focus on the memorability of specific visual stimuli. However, studies on object recognition often fail to account for how these high- and low-level features interact to promote distinct forms of memory. Here, we present a novel object database with an extensive array of visual and semantic features assessed for each image, and investigate memory for these object images in two different memory paradigms. We first collected normative feature information on 1000 object images, comprising living and nonliving items spanning 29 different categories. Semantic feature norms were collected and collated to describe complex feature statistics consistent with the conceptual structural account (CSA). Next, we conducted a memory study where we presented these same images during encoding (picture target) on Day 1, and then either a Lexical (lexical cue) or Visual (picture cue) memory test on Day 2. Our findings indicate that higher-level visual factors (via DNNs) and semantic factors (via feature-based statistics) make independent contributions

to object memory, and factors that predict object memory depend on the type of memory being tested. These findings help to provide a more complete picture of what factors influence object memorability. Furthermore, the public repository created in this project consists of useful information on the objects including, visual and semantic feature information, memorability of object images in two different memory paradigms, display and creation of multidimensional scaling plots, and downloads for feature and memory data. We hope that this object database will encourage users to interact with various kinds of information and select appropriate cut off points at different levels of novel analyses.

Acknowledgements: NIA K01AG053539

Poster Session A > Visual Memory: Encoding > Poster A25

Adding another dimension to history effects in vision: Larger serial dependence in the depth plane than in the fronto-parallel plane in virtual reality

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Saturday 8:00 am - 10:00 am EDT

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Perceptual judgments about stimulus features are biased towards stimuli presented in preceding trials. This bias, referred to as serial dependence, is thought to promote perceptual stability in a world where natural scenes are generally stable and continuous from one moment to the next. While serial dependence has been extensively investigated, to date it has only been studied using simple 2D stimuli (e.g. Gabor patches). Our current study moves the investigation of serial dependence into more natural settings by utilizing the more realistic environment offered by Virtual Reality (VR). Observers were presented with an object commonly encountered in daily life (e.g. a flashlight) and then required to report its orientation in an adjustment task within the VR environment. The distance between the observer and the object, and the plane in which the object was rotated, was manipulated. The object was rotated either in depth or in the fronto-parallel plane. In all conditions, observers' orientation judgments were biased towards the orientation presented in the previous trials, showing standard serial dependence. Larger biases were observed when the object was further away in depth from the observer, and crucially the biases were larger when the object was rotated in depth compared to the fronto-parallel plane. Moreover, a larger bias was observed on the current trial when the object in the previous trial was closer to the observer. These results indicate that the additional uncertainty added by the 3rd dimension can yield larger and more robust positive serial dependence. We discuss this in the light that serial dependence is considered to be stronger with larger uncertainty about the visual input. Given that serial dependence is considered to be an adaptive strategy in naturalistic environments, we argue that examining it in VR provides more informative and potentially more accurate insights into perceptual history biases.

Poster Session A > Visual Memory: Encoding > Poster A26

Contextual vs. probabilistic learning of target locations in scenes differentially facilitate retrieval and attentional orienting

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During visual search we quickly learn to attend to an object's probable location, efficiently sifting through clutter from the visual world to find our target. Research has supported that this process is facilitated when target-location learning is based on hippocampal-dependent spatial contextual associations (CC, contextual cueing) or striatal-based probabilistic regularities (LPL, location probability learning). Here, we tested how these different types of learning aid the utilization of established memories. In two online experiments, participants searched for targets within scenes. Depending on the scene category, the target consistently appeared at a specific location (CC), within a hemifield (LPL), or was unpredictable (random). In Experiment 1, 54 participants were subsequently tested on their memory for the hemifield and the specific location of the learned targets. Participants showed enhanced recall accuracy for target hemifield and specific target location in both LPL and CC conditions. However, when learning performance was low (low accuracy/high

reaction time), predominantly LPL facilitated memory for target hemifields, and when learning performance was high, CC facilitated memory for specific target locations. In Experiment 2, after learning, 54 participants were tested on their ability to orient attention to targets flashed either in a learned specific location or hemifield. We found greater orienting benefits for CC compared to LPL, as measured by reaction time. Together, we demonstrate that contextual and probabilistic learning systems provide utility for future retrieval of learned associations, but how these systems promote memory retrieval may be related to the quality of encoding. Further, after comparable learning conditions, attentional orienting seems more profoundly guided by contextual, compared to probabilistic regularities. Our work suggests that a more nuanced view of how these memory systems cooperate and/or compete to guide adaptive behavior is necessary.

Acknowledgements: This work was supported by The Wellcome Trust 104571/Z/14/Z.

Poster Session A > Visual Memory: Encoding > Poster A27

Contextual cueing survives allocentric and egocentric transformations

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Saturday 8:00 am - 10:00 am EDT

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Introduction: Visual search can be guided by incidentally learnt spatial configurations. This contextual cueing survives transformations like rotation (Zheng & Pollmann, 2019). Here we investigate if contextual cueing can guide search after allocentric or egocentric transformation. Short-lived trial-to-trial priming speeds visual search after both kinds of transformation (Ball et al., 2017). In contrast, the long-lasting effects of target location probability cueing occurred in an egocentric reference frame (Jiang & Swallow, 2013). To the best of our knowledge, the dependence of contextual cueing on egocentric or allocentric reference frames has not been investigated, although the robustness of contextual cueing to rotation may suggest independence of egocentric representation. Methods: In two experiments, participants (n=24 resp. n=25) repeatedly searched for a T among L-shapes in twelve displays surrounded by an upright or tilted frame. Subsequently, unknown to them, we set up four conditions: fully repeated displays (same as in the training phase), identical displays but rotated frame (only egocentric reference preserved), frame unchanged but display rotated (only allocentric reference preserved), and newly generated displays. Experiment 2 was designed in the same way as Experiment 1 but controlled the targets' absolute locations to rule out target probability cueing. Result: Preserved egocentric reference frames (Experiment 1: $t(23)=4.26$, $p<.001$ and Experiment 2: $t(24)=4.14$, $p<.001$) speeded search relative to new displays. Preserved allocentric reference frames likewise speeded search (as a tendency in Experiment 1: $t(23)=4.14$, $p=0.025$, significantly in Experiment 2 ($t(24)=3.87$, $p<.001$). Conclusion: The data show that disrupting either the allocentric or egocentric reference frame could not eliminate the search advantage for incidentally learned displays, as long as the other cue was preserved. Our finding suggests that egocentric and allocentric representations parallelly exist in implicit spatial memory, which lends additional support for the 'two-system' model of spatial memory (Burgess, 2006).

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Temporal Processing

Poster Session A > Temporal Processing > Poster A28

Auditory speed processing in sighted and blind individuals

View Poster | Visit me in Gather.Town Osprey Room on Saturday 8:00 am - 10:00 am EDT

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Space and time are strictly linked, and a multisensory experience is crucial for developing a merged representation of spatial and temporal domains, with vision scaffolding spatial representations and audition temporal representations. However, it is still unclear how temporal and spatial domains interact in the lack, for example, of the visual experience. Investigating speed perception provides a unique opportunity to study this interaction. Thus, we explored the role of vision in the use of spatio-temporal cues to discriminate the speed of moving sounds. In a two-alternative forced-choice task, ten early blind and ten sighted (blindfolded) individuals determined the speed of a target sound, by saying whether it was moving faster or slower than a reference sound. The target speed was manipulated by changing the distance traveled by the moving sound and/or its duration, based on the experimental conditions. To identify the target speed, participants could rely on spatial, temporal, or both cues. Using a discrimination contours technique (Freeman et al., 2014), we revealed that both sighted and early blind participants preferentially used temporal cues to determine the target sound's speed. Specifically, both groups followed a temporal prior that identifies as faster stimuli those that last less than the reference sound, even if that leads to a misperception of the stimulus speed in some conditions. Interestingly, early blind participants appeared to be significantly more affected by this potentially misleading temporal prior, showing impairment in speed discrimination, compared to sighted controls. To conclude, the present study adds new insights on the role of vision on human perception by showing that auditory speed discrimination is preferentially based on temporal cues and that the absence of visual experience early in life affects this ability by increasing the preference for the temporal domain.

Poster Session A > Temporal Processing > Poster A29

Modelling event duration and overlap during EEG analysis

View Poster | Visit me in Gather.Town Osprey Room on Saturday 8:00 am - 10:00 am EDT

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Event related potentials (ERP) have been an essential part of EEG analysis since its early days. Common practice is to average over many trials to get an estimate of the underlying brain response. However, many experiments contain events of variable length (e.g. due to differences in reaction times, fixation duration, stimulus duration, etc.). These varying durations are rarely considered, be it due to a lack of analysis tools or plain unawareness, in the worst case leading to biased or even nonsensical inferences about the nature of the brain. Even worse, the varying event durations often co-occur with temporal overlap of different ERPs (e.g. responses to stimulus onsets and button presses) adding further bias. We applied regression methods to simulated and real-world data and systematically explored how event duration affects the resulting ERPs and how to adequately model them. To account for the temporal overlap, we used deconvolution based overlap correction as implemented in the unfold-toolbox (https://www.unfoldtoolbox.org/) and investigated its additional influence on the ERP estimation. We find that modelling event durations as binned or linear predictors performs poorly. However, non-linear effects using spline-regression seem to be able to capture the main patterns and are thus a promising candidate for further study.

Poster Session A > Temporal Processing > Poster A30

The hand is quicker than the eye: Sensitivity to the timing of visual, vibrotactile, and bi-sensory stimulation

View Poster | Visit me in Gather.Town Osprey Room on Saturday 8:00 am - 10:00 am EDT

Mercedes B. Villalonga[1], Rachel F. Sussman[1], Robert Sekuler[1]; [1]Brandeis University

Sequences of pulses can reliably communicate temporal information, but are pulses from all modalities equivalent in this regard? For an answer, we examined temporal sensitivity with visual (V) and vibrotactile (T) pulses. In Experiment One, human subjects received sequences of ten V or T pulses. Subjects categorized each sequence as slow (mean = 4 Hz) or fast (mean = 6 Hz). In different conditions, inter-pulse intervals were either fixed (isochronous sequences) or perturbed to different levels by Gaussian temporal-domain noise. Signal detection analysis showed that tactile sensitivity was superior to visual sensitivity, and that for all but the most variable sequences, subjects were biased to label V sequences “fast” more often than T sequences. We hypothesized that this bias arose from vision’s comparatively poorer temporal acuity. In Experiment Two, we used the same stimuli in a gap detection task for a direct measure of temporal acuity. We also included a bi-sensory (VT) condition to test for an effect of bimodal cue combination. On each trial, subjects observed a pair of stimuli from the same modality condition: a single-pulse stimulus, and a double-pulse stimulus whose inter-pulse interval varied from 2-32 ms. Subjects judged which trial interval contained the double-pulse stimulus. Modality-specific gap detection thresholds showed that to successfully discriminate single-pulse from double-pulse stimuli, subjects needed longer intervals between successive V pulses than between T or VT pulses. Gap detection thresholds were similar for T and VT stimuli, suggesting that the vibrotactile component dominated bimodal

gap detection. Together, these results suggest that vibrotactile temporal sensitivity is superior to visual temporal sensitivity, and that vision may be relatively limited in its ability to convey rate information reliably.

Acknowledgements: NIGMS Training Grant T32GM132498, The Jay Pepose '75 Vision Sciences Fellowship

Poster Session A > Temporal Processing > Poster A31

No Evidence for a Single Oscillator Underlying Discrete Visual Percepts

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Saturday 8:00 am - 10:00 am EDT

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Theories of perception based on discrete sampling posit that visual consciousness is reconstructed based on snapshot-like perceptual moments, as opposed to being updated continuously. According to a model proposed by Schneider (2018), discrete sampling can explain both the flash-lag and the Fröhlich illusion, whereby a lag in the conscious updating of moving stimulus alters its perceived spatial location in comparison to stationary stimulus. The alpha-band frequency, which is associated with phasic modulation of stimulus detection and the temporal resolution of perception, has been proposed to reflect the duration of perceptual moments. The goal of this study was to determine whether a single oscillator (e.g., alpha) is underlying the duration of perceptual moments, which would predict that the point of subjective equality (PSE) in the flash-lag and Fröhlich illusions are positively correlated across individuals. Although our displays induced robust flash-lag and Fröhlich effects, virtually zero correlation was seen between the PSE in the two illusions, indicating that the illusion magnitudes are unrelated across observers. These findings suggest that, if discrete sampling theory is true, these illusory percepts either rely on different oscillatory frequencies or not on oscillations at all. Alternatively, discrete sampling may not be the mechanism underlying these two motion illusions or our methods were ill-suited to test the theory.

Poster Session A > Temporal Processing > Poster A32

A strategy for presenting computational models intelligibly

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Saturday 8:00 am - 10:00 am EDT

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Computational models are a useful tool to characterize the mechanisms underlying visual perception. They avoid the ambiguity inherent in verbal model descriptions, and, when published together with the code, they can be (re-)used by different people and their predictions can be replicated in a straight-forward way. For this reason, many journals now require authors to publish their code alongside the paper. While this is a commendable practice, we think it is not yet sufficient, because readers with little background in software engineering might still find it difficult to connect the published code with the theoretical concepts in the paper. With our increased understanding of perceptual processes, the corresponding models become more and more complex. For example, extending purely spatial models by a temporal dimension adds significant complexity to such models. The mental and computational handling of multidimensional structures is objectively difficult and makes it hard for readers to understand relevant model parts, let alone assess their adequacy. We suggest to showcase models accessibly using interactive programming tools (Jupyter). These tools naturally bridge the gap between mathematical model descriptions in the text and corresponding functions in the code. We chose a model that incorporates spatio-temporal processing characteristics of retinal ganglion cells but is still relatively straight-forward. It was presented in a recent paper (2019) in a journal that explicitly encourages the publication of code. We present and visualize functional components of the model individually, together with their respective in- and outputs, helping the reader to understand the components and their interactions. The use of an interactive tool allows the reader to tinker with parameters and observe the resulting effects. Despite best efforts, we encountered a number of ambiguities in the original authors' presentation which can be avoided with a more comprehensive approach of model presentation as the one we advocate here.

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Poster Session A > Temporal Processing > Poster A33

What determines the temporal extent of unconscious feature integration?

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Saturday 8:00 am - 10:00 am EDT

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Visual features are spatiotemporally integrated along motion trajectories. For instance, when a central line is followed by pairs of flanking lines, two motion streams diverging from the center are perceived. The central line is rendered unconscious by the subsequent flanking lines through metacontrast masking. Surprisingly, if the invisible central line is offset, the entire stream appears offset, even though the flanking lines are, in fact, straight. Further, if one of the flanking lines is offset in the other direction, the two offsets integrate and cancel each other out. This integration is mandatory and occurs only when the offsets are presented within a specific, temporal window, starting with stimulus onset and lasting for about 450ms. Here, we asked what determines the extent of this unconscious integration. Observers discriminated the perceived offset of the motion streams. In line with most models of decision making, one might expect that the window terminates as soon as sufficient evidence about the offset is accumulated. However, this is not what we found. We presented either a large offset at the first line or smaller offsets at the following lines, all in the same direction. When performance was the same in both conditions, the duration of the integration windows was identical. Hence, it does not matter whether strong evidence is presented right from the beginning or dispersed along the motion stream. When we increased the processing load by adding two further offsets at two additional lines, which, however, canceled each other out, the window duration increased slightly. Lastly, we found that absolute time determines the window duration but that the number of lines or the ISI between the lines do not. We propose that perception is a series of discrete frames, which depends mainly on absolute time, potentially on the processing load, but not on stimulus evidence.

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Poster Session A > Temporal Processing > Poster A34

Sensory processes are delayed when expectations are not met

View Poster | Visit me in Gather.Town Osprey Room on Saturday 8:00 am - 10:00 am EDT

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The effects of prior knowledge and expectations on recognition and decision-making are well-established. Detecting and recognizing objects get easier when they are presented in their usual context. Yet, related low-level sensory processing and the computational mechanisms underlying those effects remain controversial. Here we investigated behaviorally the effect of expectations on category-specific detection thresholds (Urgen & Boyaci, Vis. Res. 2021). At the beginning of each trial a task-irrelevant cue (face or house) provided information about the category of an upcoming target image (face or house) with a certain validity (75%, 50%, 100%, neutral). Next, the target image and its scrambled version were presented and backward masked on either side of a central fixation mark for a variable duration determined adaptively by a 1-up 2-down staircase procedure. Participants (N = 8) were asked to report the spatial location of the target image (2AFC). Duration thresholds were estimated in expected, unexpected, and neutral trials (in terms of cue-target category associations). Our behavioral results showed that compared to the neutral baseline, thresholds do not change in the expected trials, but they increase in the unexpected trials. Next, we show that a recursive Bayesian model can successfully predict the behavioral results. Modeling results suggest that internal parameters of the system are not altered with expectation, instead simply additional processing is required under the unexpected condition. Overall, our findings show that expectations do not speed up sensory processes, rather unmet expectations delay them. We argue that this happens because when expectations are violated further processing is required by the system. We also discuss our findings within the framework of predictive processing models and suggest that a simple neuronal model (Heeger, PNAS 2017) can parsimoniously explain the observed behavioral findings.

Acknowledgements: This work is funded by a TÜBİTAK 1001 grant (217K163) awarded to HB.

Poster Session A > Temporal Processing > Poster A35

How long does stimulus processing last?

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Saturday 8:00 am - 10:00 am EDT

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How a stimulus is processed is at the very heart of all vision research. However, there is only little research about how long the processing of a stimulus lasts. One reason is that visual processing is often explicitly or implicitly thought to be feedforward, an assumption that is however only met in few paradigms. The other reason is that it is easy to know when stimulus processing begins but it is very hard to determine when it terminates. Here, we show psychophysically that stimulus features are unconsciously integrated for about 400ms. We presented a vernier in the center of the screen followed by a series of pairs of lines, creating the percept of an expanding stream. The vernier was offset either to the left or right, the lines had no offset. Even though the vernier was rendered invisible by sequential metacontrast masking of the lines, the subsequent lines appeared as offset. If one of the subsequent lines was also offset, the offsets integrated mandatorily, i.e., observers had no access to the individual offsets. This mandatory integration lasted for about 400ms. When the line offset appeared after 500ms both offsets could be reported separately. Such windows of integration start with the sequence onset. Importantly, integration is a sophisticated and constructive process. If for example some intermediate lines are removed, the streams are no longer perceived as continuous and no integration occurs. Observers can report the offsets separately. However, when the same lines are occluded instead, integration occur. Our results offer a new view on vision because they allow substantial processing time in any type of model.

Acknowledgements: Supported by the Swiss National Science Foundation project "Basics of visual processing: from elements to figures""

Poster Session A > Temporal Processing > Poster A36

Metacontrast Masking Across Different Contrast Polarities: The Role of Late ERP Components

View Poster | Visit me in Gather.Town Osprey Room on Saturday 8:00 am - 10:00 am EDT

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Metacontrast masking has found increasing applications as a powerful methodological tool in studies of information processing and visual perception. However, the cortical mechanisms underlying this important investigative tool are still subject to debate. Although substantial metacontrast can be obtained even when the target and mask have opposite contrast polarities, previous research also indicated that the masking strength is contrast-polarity specific. In the current study, using contrast polarity as a critical experimental factor, we aimed to identify the modulations of ERPs (event-related potentials) that parallel changes in the metacontrast masking functions. Accordingly, we employed a contour discrimination task in a metacontrast paradigm combined with EEG (Electroencephalography). The behavioral performance values indicated a typical U-shaped metacontrast function for the same polarity condition. However, when the target and mask had opposite contrast polarities, the masking function became a monotonic increasing function and the masking effect was strong at stimulus onset asynchronies less than 50 ms. This shift in metacontrast function has been mainly interpreted as an increase in intra-channel inhibition of the sustained activities (i.e., parvo-dominant pathway) associated with object visibility and identity. The cluster-based permutation test on the ERP waveforms revealed an early (160-300 ms, occipital and parieto-occipital scalp sites) and a late (300-550 ms, parietal and centro-parietal scalp sites) spatiotemporal cluster. Moreover, there was a robust correlation between the modulations of potentials in the late cluster time-range and the changes in performance values. Overall, these ERP findings indicate the involvement of late inhibitory mechanisms in metacontrast masking. Although the behavioral and ERP findings do not preclude other important proposed mechanisms underlying metacontrast (e.g., inter-channel inhibition), they together suggest that the late recurrent intra-channel inhibition within the sustained pathway also plays an important role in metacontrast masking.

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Poster Session A > Eye Movements: Cognition, neural mechanisms > Poster A41

Pupil size automatically encodes numerosity

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Even when physical luminance is constant, pupil size varies with the perceived luminance and size of the visual image, and also with how attention is directed (to bright or dark features). Here we asked whether pupil size is also driven by the perceived numerosity of an array of bright or dark visual elements (with luminance held constant). We recorded pupil size while 14 adult participants viewed clouds of white or black elements presented in central vision against a gray background. The total number of pixels in the elements (and hence luminance), as well as the area covered by them (convex hull) were kept constant. Either 18 or 24 dots were displayed in a given trial. Perceived numerosity was further manipulated by connecting dot pairs with lines to create 9 or 12 dumbbell-like shapes; in the isolated-dots condition the same lines were displayed in random positions. Participants simply observed the stimuli without performing any task. Pupil size was significantly modulated by both physical and perceived numerosity. The stimulus-evoked pupil constriction or dilation was smallest for 18 connected dots, intermediate for 18 unconnected and 24 connected dots (which have the same perceived numerosity) and largest for 24 unconnected dots. The results suggest that pupil diameter is spontaneously regulated by the numerosity of an array of bright or dark elements, so more items generate a stronger response, with luminance kept constant. In addition, perceived rather than physical numerosity drives these pupillary responses. There is much evidence to suggest that numerosity is a spontaneously encoded basic visual feature. Our results further show that even without an explicit task, perceived numerosity of an array of elements drives measurable automatic responses not subject to voluntary control: pupil size changes.

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Poster Session A > Eye Movements: Cognition, neural mechanisms > Poster A42

Watching people decide: decision prediction using heatmaps of reading of a decision-support document

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Introduction: Previous studies show that reading behavior varies with the readers’ Levels of Expertise (LoE) in a task area. Except for LoE, other factors like acquired information plays a role in this process. In the area of health policymaking, people read supporting documents to inform their decisions. This leads to a natural question: could it be possible to predict the decisions based on the reading pattern of the supporting document on top of their LoE? Method: We collected eye tracker data from a group of people with various LoE. We used the heatmaps as the primary pattern of reading. These were prepared using the average fixation duration of the individuals. First, we performed a hierarchical cluster analysis with the pairwise correlation matrix between the heatmaps, to see whether heatmaps as A single feature were effective to reach our goal. In the second step, we made an ensemble of the features of the reading patterns from the heatmaps and pupillometric features, and LoE, with the decision made by the participants as an outcome, using AdaBoost regressor. In this decision-making task, one could choose one among expensive, prudent, and midway. Result: The first analysis reveals to us that there are a minority number of individuals who read less than the majority group. This minority group tends to make decisions in the extremities. The result of AdaBoost-regressor, shows us 1. the LoE is a stronger feature than the patterns of reading to predict the decision to be taken. 2. the pupillometric features are weaker feature than the reading patterns from the heatmaps for our task. Conclusion: Reading patterns could be useful

for forecasting a decision, given the LoE of the individual. Heatmaps can be used as both qualitative and quantitative measures for reading patterns.

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Poster Session A > Eye Movements: Cognition, neural mechanisms > Poster A43

Predicting cognitive performance using eye-movements, reaction time and difficulty level.

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Cognitively challenging tasks require complex coordination of information beyond visual input. Predicting accuracy on such tasks has potential applications in education and industry. Task difficulty is associated with increases in reaction time and variation in eye tracking indices. Critically, machine learning has not yet been used to predict accuracy on cognitive tasks with multiple difficulty levels. We report data on 57 (34 females; 20-30 years) participants who completed visuospatial tasks of mental attentional capacity with six levels of difficulty while their eye movements were recorded using EyeLink Portable Duo SR Research eye-tracker with 1ms temporal resolution (at 1000 Hz frequency) in remote head-free-to-move mode. Results show that task accuracy scores can be robustly predicted when all variables (e.g., eye-tracking, difficulty level and reaction time) are considered together (R2 = .80). Reaction time, difficulty level and eye tracking metrics are also effective independent predictors with R2 equaling .73, .58, and .36, respectively. Analyses for feature importance suggest eye-tracking indices with the most importance for the models include the number of fixations, number of saccades, duration of the current fixation and pupil size. Notably, our machine learning algorithms target a prediction question, rather than a classification one, and the current algorithm can be useful for future research and applications in other contexts where visuospatial processing is required. Theoretically, findings show common and distinct metrics that can inform theories of cognition and vision science.

Acknowledgements: Support is gratefully acknowledged from the Russian Science Foundation (#17-18-01047)

Poster Session A > Eye Movements: Cognition, neural mechanisms > Poster A44

An attentional limbo: Between saliency-driven and goal-driven selection, saccades become momentarily non-selective.

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Both saliency and goal information are important factors in driving visual selection. Previous work has shown that these processes follow different time courses: saliency-driven selection prevails shortly after the presentation of the onset of the visual scene, after which goal-driven biases towards task-relevant stimuli take over. Here, we report evidence for an intermediate period during which eye movements appear to be neither driven by saliency nor by the task goal. We used a simple selection task in which we presented either a salient target with a non-salient distractor, or a non-salient target with a salient distractor. Subjects were asked to make a speeded eye movement to the target. In line with previous findings, we found that short-latency saccades were driven by saliency, whereas long-latency saccades were driven by task relevance. Strikingly, in between these different selection episodes, we observed a time window of a few tens of milliseconds during which eye movements were neither driven by saliency nor by relevance. During this “attentional limbo”, subjects were equally likely to select the non-salient distractor as they were to select the salient target. We show this for saliency and relevance defined within the same dimension (orientation) and within different dimensions (orientation and color). Furthermore, we show that the onset of this period of non-selectivity is modulated by eccentricity. We hypothesize that during this time window of non-selectivity initial signal processing of the salient and non-salient item have both completed, thus eliminating the relative saliency effect, while differential goal-driven modulation has not yet started. In this period, the eyes momentarily rely on information regarding signal presence, without being biased by saliency and goals.

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The Price of Breaking the Tyranny of Film: The cognitive demand of top-down processes

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Film-viewers' eye-movements seem largely disconnected from their comprehension; eye-movements rarely deviate from focal narrative elements, regardless of comprehension differences (Loschky et al., 2015; Hutson et al., 2017), termed the Tyranny of film. This suggests bottom-up film features overwhelm top-down attentional control. However, viewers' eye-movements did deviate from focal narrative elements when given a task irrelevant to comprehension, suggesting viewers used volitional top-down control. However, do viewers naturally engage in volitional top-down control during film viewing or it is too cognitively demanding? Additionally, the role of mandatory top-down attention (e.g., culture) was investigated. Specifically, does mandatory attention have a role in film-viewing or are the bottom-up film features too strong? Participants from the US and Japan viewed film clips with different task goals and levels of attentional demand while eye-tracked. Participants had a primary goal-related task of either watching a film clip for comprehension (Comprehension Condition) or drawing a map of the film space from memory (Map Condition). Participants had a secondary task (cognitive load) on half the trials to increase attentional demand. Results show mandatory attentional selection differences, where Japanese participants were relatively more exploratory during film viewing compared to US participants. Additionally, we replicated and extended volitional attention effects of goal manipulation (Hutson, et al., 2017). Specifically, a volitional task irrelevant to comprehension created more exploration in eye-movements compared to participants who were viewing for comprehension. Finally, evidence shows volitional attention is cognitively demanding during film viewing; this was only true for our Japanese participants. Exploratory analyses showed US participants managed their cognitive load by trading off their dual-task paradigm; suggesting a lower cognitive load, which would explain our lack of an effect for US participants. In sum, the Tyranny of film can be broken, but it comes at the price of cognitively demanding tasks.

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Transsaccadic peripheral-foveal associations for familiar and novel objects

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The theory of transsaccadic feature prediction (Herwig & Schneider, 2014) postulates that through everyday experience the visual system implicitly associates foveal and peripheral information corresponding to the same object. Therefore, peripheral information can be used to predict associated foveal object information for recognition, and foveal information can be used to predict peripheral information for visual search. Here, we tested whether peripheral-foveal associations are better for familiar than for novel objects in two different experiments. In both experiments, participants were trained on a set of novel objects to implicitly associate peripheral and foveal information corresponding to those objects, by using a sham transsacadic orientation discrimination task. On the day after, observers completed a recognition task to measure their familiarity with the trained objects. Following the familiarity measurement, participants in the first experiment performed a 3-AFC peripheral identification task where they needed to pick the foveal target that matched the briefly presented familiar or novel peripheral probe. Participants in the second experiment performed a transsaccadic change detection task where a familiar or novel peripheral object was swapped or not swapped with another object either immediately after the saccade or after a 300 ms blank. We found an advantage of familiar over novel objects in the peripheral identification task of the first experiment. In the transsacadic change detection task of the second experiment, we found an advantage for the blank condition, reproducing the well-known blanking effect. More importantly, we found that intrasaccadic change detection performance with and without blank was better when either one of the objects was familiar. The advantage of familiar over novel objects in both experiments might be caused by two mutually non-exclusive effects: improved peripheral recognition of familiar objects and strengthened peripheral-foveal association for familiar objects.

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Poster Session A > Eye Movements: Cognition, neural mechanisms > Poster A47

Machine learning, eye movements and mathematical problem solving

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Major discoveries in technology and science often rely on mathematical skills. Mathematical knowledge is founded on basic math problem solving such as addition, subtraction, multiplication, and division. Research shows that problem solving is associated with eye movements that index allocation of attention. Machine learning has been used with eye-tracking metrics to predict performance on real-life user efficiency tasks and classic puzzle games. Critically, no study to date has evaluated eye-tracking metrics associated with mathematical operations using machine learning approaches to classify trial correctness and predict task difficulty level. Participants (n = 26, 20-30 years) viewed mathematical problems in three levels of difficulty indexed by 1-, 2-, and 3-digit problems along with four possible answers, while their eye movements were being recorded. Eye-tracking data were acquired with EyeLink Portable Duo SR Research eye-tracker with 1ms temporal resolution (at 1000 Hz frequency) in remote head-free-to-move mode. Results show that trial correctness can be classified with a 0.81 ROC AUC score based on 5 fold cross-validation. Predicting task difficulty level of each trial was attained with 72% accuracy, which is significantly better than the random prediction (i.e., 50%). The most important features for both machine learning models include metrics associated with current pupil fixation, current saccade amplitudes, and current fixation duration. Theoretically, findings contribute to theories of mathematical cognition. Practically, algorithms can contribute to further research in mathematical problem solving and machine learning, which potentially has applications in education in terms of assessment and personalized learning.

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Poster Session A > Eye Movements: Cognition, neural mechanisms > Poster A48

Detection, Inspection and Re-Inspection: A functional approach to gaze behavior towards complex scenes

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Traditional approaches examining fixations towards natural scenes either focus on their spatial distribution, or aim to explain their exact sequence. Whereas heat-maps potentially conflate fixations serving different perceptual functions, scan-paths may aim for an unnecessary level of detail. Here, we introduce a novel way of analysing fixations. We hypothesize that fixations mainly serve three goals: Detection, Inspection and Re-Inspection of visual objects. Detection (D) for foveal vision is achieved by the first fixation landing on a given object, Inspection (I) by successive scanning immediately after Detection, and Re-Inspection (R) following the intermediate exploration of other objects. N = 101 participants freely viewed 700 images of everyday scenes. To test consistency within and differences between D, I and R fixations, we generated separate fixation maps for each category and image, separately for two subsets of observers. Results indicate large consistencies for D, I and R fixations across observers, with maps sharing 95%, 93% and 88% of their variance on average. At the same time, the shared variance between D, I and R was only 65% on average. To explore the nature of these differences, we computed the proportions of D, I and R fixations landing on different types of objects and found they could vary substantially. For instance, 57% of Inspection, but only 34% of Detection fixations landed on Text. Finally, we probed individual differences in the proportions of dwell time allocated to D, I and R. These individual biases towards D, I or R were both, considerable and highly consistent across images (all r > .96). Taken together, the DIR model can capture distinct aspects of fixation behavior on an observer-general and individual level. We propose it as a useful level of description for analysing and understanding the diverse perceptual functions of gaze behavior.

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Poster Session A > Eye Movements: Cognition, neural mechanisms > Poster A49

Object-context inconsistencies affect gaze behavior differently than predicted by contextualized meaning maps

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The role of semantic information in eye-movement control is increasingly recognized. One prototypical effect is particularly well studied: objects that are semantically inconsistent with their context (e.g., a shoe on a bathroom sink) attract more fixations than semantically consistent objects (e.g., a hair brush on the sink). The typical interpretation of this effect argues that fixations are driven towards inconsistent objects because they “contain greater meaning”. In the current study, we directly tested this explanation using contextualized meaning maps (cMMs), a method to quantify the spatial distribution of ‘meaning’ across an image. These maps aggregate crowd-sourced ratings of the meaningfulness of local images-patches into a distribution over an image. Importantly, patch-ratings are provided by raters who know the image, from which the patches originate. Therefore, when providing their ratings, raters can take into account the extent to which objects on the patches are consistent with the scene context. In our first experiment, we collected eye-tracking data and created cMMs for scenes, in which the consistency of objects with the scene was experimentally manipulated. As predicted, human observers fixated more on inconsistent vs. consistent objects. However, if anything, raters rated patches containing semantic inconsistencies as less meaningful, challenging the long-held notion that semantically inconsistent objects “contain greater meaning”. This finding was confirmed in Experiment 2, where 140 raters rated a carefully selected set of image-patches. Patches extracted from the same location within a scene were rated as less meaningful when the patch contained inconsistent, rather than consistent, objects. In summary, we demonstrated that, in contrast to a long-held view, semantically inconsistent objects might be experienced as less (not more) meaningful than their consistent counterparts, and that cMMs do not capture prototypical influences of image meaning on the guidance of human gaze.

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Decoding of visually guided and interceptive saccades from area LIP of macaque monkeys

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Humans and non-human primates (NHPs) use a combination of saccades and smooth pursuit when tracking a suddenly appearing moving visual target. Previous behavioral studies have shown initial (so called interceptive) saccades to be spatially accurate. This is remarkable since it requires to extrapolate the motion direction and speed of the target and to anticipate the delays induced by the programming and execution of the interceptive saccade. The neural basis of this process is still under debate. The Lateral Intraparietal Area (area LIP) is part of the saccadic control network. Its neurons show peri-saccadic activation that is dependent on the saccade trajectory, but the spatial tuning is rather broad. We have shown before that LIP-activity allows to decode target position and amplitude of interceptive saccades when saccade and pursuit direction are co- or anti-aligned (1-D task). Here, we probed decoding in full oculomotor space (2-D task). We recorded peri-saccadic activity from 105 neurons in two macaque monkeys. In each trial, an initial step of the saccade target was followed by its movement in one of eight directions. In our data analysis, we first determined the tuning of neurons during saccades towards stationary targets and then trained a neuronal network to decode the saccade landing point from the combined activities of the neuronal population. We found that a combination of even a relatively small number of 50 tuned neurons allowed to predict the saccade end-point with an accuracy of <1°. In a

second step we used the same previously trained neuronal network to predict the landing points of interceptive saccades. We found that the prediction was successful, however, it was less accurate than for the saccades towards stationary targets. We conclude that interceptive saccades in full 2-D space are represented in population activity in area LIP.

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Dissociating cognitive effects and stimulus properties during pupil size measurements in response to product images

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Pupil size changes are often used in the context of object recognition and affective processing. Compared to those evoked by physical stimulus properties, the magnitude of pupil size changes due to cognitive processes is small. Yet, many existing paradigms do not dissociate these effects. We propose a paradigm for dissociating the effects due to stimulus properties and cognitive processing that adapts the pupil to physical stimulus properties prior to the presentation of an intact stimulus image. To test this paradigm, we compared pupil responses of 15 adults living in Canada (age: M = 23.2, SD = 4.33; female = 10) to validated familiar (Canadian) and unfamiliar (European) product images in a passive viewing task. Intact images (3000 ms) were masked by pixel scrambled image versions (1000 ms before and after) to adjust the pupil to the images' luminance, contrast, and colours. After preprocessing (e.g., blink interpolation, outlier detection and downsampling), pupil dilation at all time points within each single trial was subtractive baseline corrected using the median of the last 500 ms of the preceding scrambled image mask of the same trial. Results indicate successful tracing of a cognitive brand familiarity effect on the individual participant level (up to 90% of participants showing the same effect) resulting in mean pupil size changes of about 15% compared to the individual average dynamic pupil size range during the experiment. A temporal cluster-based bootstrapping analysis identified and dissociated two temporal effects (500–800 and 1400–3000 ms post onset of the intact image) originating from separate product categories. The proposed paradigm successfully traced cognitive effects while precluding typical stimulus property confounds. This paradigm could be applied to any visual image that elicits cognitive responses, such as product images used to understand consumers' cognitive processing across various viewing, search, and choice tasks.

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Gaze behaviour: a window into quantifying task difficulty and performance using the Tower of London Task

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Actively deciding where to direct our gaze is crucial to the acquisition of visual information regarding our surroundings. Previous studies have demonstrated the potential of examining gaze behaviour to establish overt indices of cognitive processes, such as attention, visuospatial planning and problem solving. The current study aimed to characterize the eye movement pattern during visuospatial planning and problem solving using the Tower of London (TOL) task. Participants (n=9) were shown a series of pictures depicting coloured balls arranged in three columns above fixation (i.e., Goalspace) and below fixation (i.e., Workspace). The task was to plan and execute the shortest movement sequence required to match the ball arrangement in the workspace to that of the goalspace. Participants completed the task across 4 difficulty levels (i.e., optimal sequence lengths 3-6). Our results demonstrated that as task difficulty increased, dwell time, saccade frequency, gaze alternations between goal- and workspace, and saccade path length increased significantly ($p<0.01$). Notably, non-optimal trials, where participants used more moves than necessary to

solve the problem, were associated with longer fixations in areas of the display that were not relevant to the task goal during the initial planning interval (X=375 ms) compared to optimal trials (X=285 ms) (p=0.034). This suggests that fixating on irrelevant areas might interfere with information processing and problem solving. Furthermore, analysis revealed that initial gaze location had a significant influence on initial planning time. Specifically, trials with initial fixations directed to the goalspace were associated with longer initial thinking times (X=7606 ms) compared to the workspace (X=5084 ms) (p=0.021). This finding suggests that initial gaze location contributes to the efficiency of TOL performance. We conclude that gaze behaviour analyses provide useful insights into task difficulty and corresponding behavioural performance.

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High-Resolution Eye-Tracking during Natural Real-World Interaction

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Humans exhibit surprisingly fine control of their eye movements. Numerous recent studies, drawing from a range of visual tasks, have revealed oculomotor precision far superior to what previously assumed (e.g., Intoy & Rucci, Nature Communications, 2020). Because of technical challenges, reliable high-precision measurements have traditionally required strict head immobilization. During natural viewing, however, eye movements co-occur with head movements and both contribute to shape the luminance stream entering the eyes. The need, therefore, emerges for extending high-resolution oculomotor measurements to normal head-free viewing. A well-known exception to the head-immobilization requirement is provided by the seminal work by Steinman and colleagues, who developed a coil-based approach (Revolving Field Monitor; Steinman, 1995) to precisely record eye movements while the head is free to move normally. Building on this pioneering work, here we present a system that integrates a custom scleral coil eye-tracker with a motion capture system to simultaneously track eyes, head, and hand movements with high-precision. Eye-tracking is achieved by means of three, orthogonal, oscillating, magnetic fields, which are continuously tuned to maintain high uniformity in the central 1 m3 region. Voltages induced by the field are collected by coils embedded in silicon annuli placed on the observer’s sclera and on a tightly fitting helmet. A passive motion-capture system, selected to minimally interfere with the magnetic fields, tracks head translations, hand movements, and all rigid objects involved in experiments. The integration of these two systems enables precise localization of the line of sight in the scene and reconstruction of the visual input to the retina. We report measurements of head and eye movements with arc-minute resolution in a variety of everyday tasks such as needle threading, sorting small objects, and reading fine print. Our results confirm a remarkably fine degree of oculomotor control as the observer interacts normally with the scene.

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Rethinking the center bias: from fixations to saccades

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When sampling eye-fixations from observers that view natural scenes freely, a consistent pattern emerges where fixation density is highest near the center and decreases away from it. Typically, this center-bias is modeled as a normal spatial distribution of eye-fixations across complete scanpaths, and indeed, such a model was shown successful in facilitating better computational prediction of fixations. However, this view of the center-bias offers little information about any spatio-temporal effects that the center-bias may have during viewing. In the present work, we examine issues like that by analyzing saccades rather than fixations. Moreover, we also focus on a different representation of saccades where saccade orientation and amplitude are separated, examining how they vary as a function of spatial origin and their time/order during the scanpath. The results show that the center-bias is manifested throughout the duration of

viewing in both orientation and amplitude. Based on these observations, we propose a more elaborate model of the center bias, which can be used to estimate where observers tend to fixate next. Finally, we show that the proposed model explains the distribution of eye-fixations better than previously suggested models.

Acknowledgements: We acknowledge the support of the Frankel center for Computer Science research at BGU

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Cognitive influences on fixational eye movements during visual discrimination

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Most visual information is acquired during fixation. While saccades are known to be driven both by sensory information and cognitive factors, the role of cognitive factors in fixational eye movements (FEM) is largely unknown. To probe these influences, subjects were asked to discriminate between two foveally-presented letters (1.5 degrees) superimposed on visual noise whose contrast was adjusted to reach ~75% correct performance. Eye movements were monitored by a digital dual-Purkinje-image eyetracker. Trials were organized in blocks with a fixed letter pair, each letter presented in 40% of the trials. 20% of trials contained only noise. We built a computational model to choose letter pairs for which FEM trajectories were likely to affect performance. The model used previously-measured FEM trajectories to generate time-varying firing rates of LGN neurons from linear spatiotemporal receptive fields. For each trajectory, a Bayesian decision stage pooled across neurons. This yielded a prediction of discrimination performance for each candidate letter pair and each FEM trajectory, which was similar, on average, to human performance. Among multiple letter pairs examined, EF and HN discriminations showed the largest dependence on the FEM trajectories. Data from two subjects suggests several influences of cognitive factors on FEMs. For microsaccades, starting and landing points differed: both tended to be below center in EF trials, but near center for HN. Microsaccade directions were more often upward for EF, but more often diagonal for HN. Drift statistics also differed: the velocity distribution was biased towards vertical for EF, but more isotropic for HN. Interestingly, most of these findings were present in the noise-only trials of each block, suggesting that they can be driven by task knowledge, independent of the sensory stimulus.

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Attentional strategies during mental arithmetic

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Eye-tracking is widely used in research of attentional strategies in tasks with visual representations. Strategies improve with learning and many have examined differences in attention allocation between experts and novices. Research show that when math problems are presented on the screen with response options, novices fixated more on response options that included distractors, whereas experts fixated more on the math problem and the correct answer. If experts and novices apply their attention on different parts of the scree these strategy differences would also be observable when comparing high and low performers. Participants (N = 26; 20-30 years), were non-math university majors who completed the Parametric Math Task (PMT; Konopkina, 2019) while their eye movements were recorded in a remote head-free-to-move mode. The PMT contains mathematical problems of addition, subtraction, multiplication and division with three levels of difficulty. Individuals who scored above median were high performers and below were considered as low performers. Data were analysed by evaluating dwell time (total duration of fixation) to the math problem area (top of screen) and response options areas (bottom of screen). Results showed that high performers and low performers were significantly different in their dwell times for two interest areas: problem area and distractor responses (problem area: $p = 0.029$, Cohen's $d = 0.92$; distractor responses: $p = 0.018$, Cohen's $d = 0.99$). Findings indicate that high performers spent significantly more time on the math problem area of the screen whereas low performers spent more time on distractor options. In educational practice, knowledge of looking times and locations may be indicative of strategies used by the problem solvers.

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Scene Perception: Neural mechanisms

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Retinotopic organization of high-level visual regions in the human brain

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The visual system continues beyond the well-documented retinotopic early visual areas, V1 to V4, through to category-selective high-level visual areas within visual cortex. Previous work on retinotopic organization has shown that early visual areas are retinotopic, but the organization of higher-level visual regions is not as well documented. The relationship between receptive field size and eccentricity plays a role in how information is pooled and transmitted from early-level visual areas to high-level visual cortex. Therefore, the anatomical organization of receptive field properties provides insights into the visual processing pipeline. In our study, we mapped the relationships between function and organization of population receptive fields (pRFs) within visual cortex by way of their anatomical organization within four functionally localized visual processing regions: FFA, OPA, PPA and LOC. The pRF parameters were algorithmically fit using code from Kay (2013) to voxels in the Human Connectome Project (HCP) dataset, made publicly accessible by Benson and Winawer (2018), and mapped onto their respective anatomical locations of the four functionally defined high-level visual areas. The high degree of power available in the data from 181 subjects was collected using functional MRI at 7 Tesla makes the comparison of form and function especially informative of the processing capacity and specialization of each of the high-level visual areas. The resulting anatomical maps of the retinal field size and eccentricity along the three cardinal neuroanatomical axes show that the organization of the receptive fields generally follows a pattern of small retinal field size in the posterior areas and larger retinal field size in the anterior areas, which indicates that in addition to retinotopic mapping in these areas, a gradient of retinal field sizes exists along the posterior to anterior axis.

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Local Symmetry in Human and Artificial Neural Networks

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Yongzhen Xie[1], John Wilder[1], Morteza Rezanejad[1], Dirk B. Walther[1]; [1]University of Toronto

We can rapidly identify the image of a scene as a beach, a forest, or a highway. This ability relies in part on perceptual grouping cues. Interestingly, past studies found that both the human visual system (HVS) and convolutional neural networks (CNNs) are sensitive to and benefit from perceptual grouping cues such as local symmetry in scenes. Yet, we still do not know exactly how local symmetry facilitates scene categorization and whether HVS and CNNs use the cue in a similar manner. In the present study, we explore this question with representational similarity analysis (RSA), in which we compare the scene representations of the HVS with those of the CNN VGG16. Specifically, for the HVS, we computed representational dissimilarity matrices (RDMs) for ten regions of interest (ROIs) in the visual cortex using the BOLD5000 dataset. For VGG16, we created an RDM for each convolutional layer. Subsequently, we measured correlations between the RMDs for the ROIs and VGG16 layers. Moreover, we correlated all RDMs to a symmetry dissimilarity matrix (SDM) based upon the local symmetry in each scene. Consistent with previous results, we found that half of the participants had high correlations between the RDMs and SDM for low-level visual areas (e.g., V1). However, half showed high correlations for mid- to high-level areas (V4 and RSC), suggesting some variability among observers. We also found that later layers of VGG16 exhibited stronger associations with the SDM than earlier layers. We expected such a finding on a feed-forward network like VGG16 because local symmetry inherently involves longer-range relationships, which are present in higher layers due to their large receptive fields. To conclude, although local symmetry influences both the HVS and VGG16, the two systems process this cue differently, likely due to architectural limitations of feed-forward neural networks.

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Using a novel, stimuli-driven approach to uncover a robust image feature that drives human visual scene processing

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Human neuroimaging studies have revealed a dedicated cortical system for visual place, or “scene” processing. But what are the stimulus features that define a scene, and thereby engage visual scene processing? Here, we proposed a novel, stimuli-driven approach to identify a scene-defining stimulus feature. We hypothesized that if there exists a visual feature that humans use to recognize a scene, then such a feature will 1) be common in visual scene, but not non-scene, stimuli, and 2) selectively engage neural and behavioral visual scene processing. In study 1, we analyzed thousands of naturalistic images and found that, across most scenes, there is a vertical luminance gradient (VLG), with the top half of a scene image brighter than the bottom half; moreover, VLG is prominent in scene, but not object, stimuli. In study 2, using fMRI data from BOLD5000, we found a positive and significant correlation between the amount of VLG in naturalistic images and the response in the scene-selective cortical regions, but not in early visual cortex, hinting at a potential role of VLG in driving cortical scene selectivity. Thus, in study 3, using tightly controlled VLG stimuli, we directly tested the role of VLG in driving cortical scene selectivity. We found that the scene-selective cortical regions, but not early visual cortex nor an object-selective region, respond selectively to images of VLG. Finally, we tested for the relevance of VLG for behavioral scene recognition by disrupting VLG in scene images via image rotation and testing participants’ ability to remember these images (study 4). Indeed, we found that image rotation selectively impaired behavioral recognition of scene, but not object, images. Together, these results suggest that VLG is a visual feature that humans use to selectively engage visual scene processing, and call attention to the relevance of stimuli statistics for visual processing.

Acknowledgements: This work was supported by a National Eye Institute (NEI) grant (R01EY029724).

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Categorical and analog representations of spatial directions in visual scenes in behavior and the brain

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Knowing where to go and how to get there requires computing spatial directions in visual scenes. Despite high variation in detail across real-world environments, the visual system is quite capable at efficiently and automatically extracting spatial directions from visual scenes (Bonner & Epstein, 2017). People also comprehend spatial directions across distinct formats (words, maps, visual scenes), which require distinct visual computations, yet result in highly similar representations for action (Weisberg, Marchette, & Chatterjee, 2018). Here, in a pre-registered experiment, we collected original behavioral data on 500 images from the Scenes dataset used in the BOLD5000 study (Chang et al., 2019). We recruited 94 subjects to perform one of two behavioral tasks on a normed subset of 100 images each. In a categorical task, subjects indicated which spatial directions were presented by clicking boxes with named spatial directions (e.g., 'left', 'sharp right', 'ahead'). In an analog task, subjects used their mouse to draw up to 7 spatial directions, beginning from the bottom center. After removing subjects who failed an attention check, we calculated the correlation between images for the two behavioral tasks by averaging all participant responses per image (i.e., we calculated the representational dissimilarity matrix, RDM, per task). Comparing behavioral tasks, we found a significant correlation across images ($r(500) = .28$, $p < .001$). Exploiting the fMRI dataset collected in the BOLD5000 experiment, we calculated the correlation between each behavioral experiment RDM and the RDM for the BOLD signal in visual scene regions (early visual cortex, OPA, PPA, and RSC). In a preregistered analysis, we observed that correlations between the analog task and visual regions were higher than correlations for the categorical task and visual regions, which did not reach significance. In sum, these findings are a pre-registered replication and suggest a novel dissociation between

behavioral representations of visual scenes.

Acknowledgements: The authors acknowledge the following funding sources to SMW: NIH-1K01AG070333-01

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A river runs through it: Brain representations of segmented environments

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Spatial environments are often segmented into multiple regions or compartments. How is this spatial segmentation represented in the brain? Previous studies have suggested three possible mechanisms: grouping (boundaries warp the global map, making locations in different segments appear more distant than they actually are); schematization (locations are coded with respect to environmental boundaries, in a way that generalizes across segments); and remapping (each segment is represented independently, with no integration into a global map). To test these possibilities, we taught participants the locations of 16 objects within a segmented virtual environment and then used fMRI to assess location codes for these objects. The environment consisted of a virtual courtyard transected by a river that divided it into two geometrically identical segments. Visibility and spatial relations between objects were balanced to be identical within and between segments. After training, participants' distance estimations and free recall order were affected by the spatial segmentation, suggesting that their mental representations were affected by the presence of the river. Analysis of multivoxel fMRI activity patterns revealed that spatial relations between objects were coded in the hippocampus, occipital place area (OPA) and retrosplenial complex (RSC). Notably, OPA and hippocampus coded schematic representation of the individual segments, such that objects in geometrically equivalent locations within the two segments were represented as being spatially similar, while RSC coded a global map of the environment. We did not find evidence for grouping or remapping. Our findings suggest that spatial segmentation can be induced by topographic feature of the environment even when all parts of the environment are co-visible, and that segmented environments are encoded using a combination of schematic representations of the segments and a global map.

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Representation of spatial relations between multiple faces, bodies or people in the visual cortex

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Recognition of social entities such as faces and bodies is a primary step to represent social events such as interactions. Another important requirement is to process spatial relations between those social entities, which can provide a first assessment of the type of interaction taking place. For example, face-to-face bodies are more likely to trigger representation of interaction than two bodies back-to-back. We have previously shown that regions for face and body perception in the visual cortex also encode spatial relations between multiple full-bodies, distinguishing between face-to-face and back-to-back body dyads. Within a body, however, the direction of face and rest-of-the-body is not always congruent, which raises the possibility that the two might be processed independently in visual areas. We addressed this, by examining whether: a) visual encoding of spatial relations is category-specific in the sense that face-specific areas care about relationships between faces and body-specific areas care about relationships between bodies; and b) whether there are visual areas that encode for whole-person generalizing across bodies' and faces' direction. We used functional MRI on healthy male and female subjects, to measure the brain activity in response to dyads of faces and head-blurred bodies presented face-to-face or back-to-back. We found higher activity for facing (vs. nonfacing) head-blurred bodies in functionally localized body-specific visual areas only, and higher activity for facing (vs. nonfacing) faces in functionally localized face-specific visual areas only. Using multivoxel pattern analyses, we identified a region that generalizes across body and face direction in the lateral occipital cortex. This new region might integrate signals from category-specific (i.e., face and rest-of-the-body) visual areas to form a representation of relationship between people.

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Neural Taskonomy: Explaining high-level visual processing of natural scenes using task-derived representations

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What kind of information does the human brain use when we perceive a natural scene? We investigated this question using representations from 20 visually task-specific deep neural networks trained on natural scenes. Using whole brain data from two of the largest fMRI datasets on natural scenes, NSD (Natural Scene Dataset) and BOLD5000, we built voxelwise encoding models that use network representations learned individually for each task to predict brain responses for viewing these scenes. Our results show that networks trained on 2D and 3D tasks explain distinct variance in the brain. In particular, we found that high-level visual processing is better explained by 3D representations. Moreover, those neural network models that learned to focus on different images regions to perform their tasks were able to predict distinct receptive fields along the visual pathway. In aggregate, the individual brain prediction maps from each task representation enabled us to recover a landscape explicating how task-related information is processed across the brain. More generally, we suggest that using representations from a pool of task-driven deep neural networks, provides a means for combining the power of deep learning in extracting complex representations with interpretability to better explain complex processes in the human brain.

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Brain networks dynamically resolve basic algorithmic functions with task-specific strategies

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A key challenge in neuroscience remains to understand, from a systems perspective, where, when and how brain networks represent and dynamically transform sensory information for behavior. To address this challenge, we set up a visual decision task that requires brain networks to resolve the basic algorithmic functions of computation theory--ie. XOR (N = 5), AND (N = 5) and OR (N = 5). We separated the two visual inputs in space (so each initially projected in contra-lateral occipital cortex) and time (with a 1 s delay between each input) to constrain their subsequent representation, transfer and integration across hemispheres for decision behavior. Each trial started with one lateralized input (ie. dark or clear lens of a pair of glasses on a face) when the other input was greyed out for 1s, following which this second input became dark or clear. Using linear regressions, we decomposed concurrently recorded 248-sensor magnetoencephalography (source localized with an LCMV beamformer) into different systems-level dynamic processes that (a) linearly represent and transfer the left and right visual inputs (ie. left and right dark vs. clear lens) and then (b) nonlinearly integrate them for task decisions to finally (c) influence behavioural reaction times (RT). Next, we investigated task-specific strategies. Specifically, the first input can logically disclose the AND and OR response on trials when it is clear in AND and dark in OR, whereas XOR always requires integration of both inputs. RTs were indeed shorter when the first input disclosed the task, but neural synergistic interactions (ie. input integration) were stronger when both inputs had to be integrated (i.e. on trials when the first input did not logically disclose the AND and OR tasks). Finally, this difference in synergistic integration related to behavior on trial-by-trial basis in the AND and OR, but not XOR tasks.

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The stuff of natural scenes: probing human property judgments of textures, materials, and other amorphous scene components with convolutional neural networks

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Neha Nandiwada[1], Caterina Magri[1], Michael Bonner[1]; [1]Johns Hopkins University

Scenes are composed not only of discrete objects with defined shapes but also complex visual “stuff” in the form of amorphous textures and patterns (e.g., grass, bricks, smoke). Many behaviorally relevant properties of scenes can be quickly recognized based solely on the stuff they contain—e.g., hotness of fire, hardness of concrete, fragility of glass. Though much work has explored how the human visual system represents individual objects, less is known about how we process the amorphous stuff that makes up most of the visual environment. Furthermore, an open question is to determine what classes of computational models can account for the human ability to rapidly detect a rich set of high-level properties from a brief glance at a patch of visual stuff. To address these questions, we developed a dataset of 500 high-quality images from 50 categories of textures encountered in real-world environments, and we collected annotations of readily identifiable qualitative properties of these images (e.g., material properties, haptic properties, semantic attributes). In preliminary investigations, we sought to determine whether computational models trained for object recognition also yield representations that are useful for predicting the qualitative properties of visual stuff. Our findings show that while many perceptual and haptic properties (e.g., bumpiness) are equally well-predicted by both supervised and untrained convolutional neural networks, high-level semantic attributes (e.g., naturalness) were much better predicted by supervised models. Nonetheless, all models failed to reach the noise ceiling for the majority of the property annotations, demonstrating that further work is needed to account for the richness of human stuff perception. Our dataset will provide a critical benchmark for computational models and will be useful for follow-up studies that seek to understand how humans recognize the many qualitative properties of the stuff in their visual surroundings.

Object Recognition: Features and parts

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Accessing meaning from different visual inputs: Word and object frequency effects in recognition behavior.

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Object and word recognition are both processes that transform visual input into meaning. When we read words, the frequency of their occurrence strongly modulates recognition performance. With more object-labels available in large real-world image datasets, one can now estimate the frequency of occurrence of objects in scene image databases ("object frequency"). Here, we apply this new "object frequency" measure to investigate frequency effects in word and object recognition. Besides, we compare these measures with established word frequency measures for predicting behavior in a natural vs. man-made categorization task (Experiment 1) and a same-different priming task (Experiment 2) involving words and images of object concepts. In Experiment 1, only a word-based frequency measure (SUBTLEX word frequency based on movie subtitles) resulted in a facilitatory effect (i.e., faster responses to frequent stimuli) on both words and object recognitions. In Experiment 2, we replicated the facilitatory SUBTLEX-frequency effect, for both stimulus types, when the task included cross-modal priming (i.e., word-to-object or object-to-words) but notduring repetition priming. Likewise, only in the cross-modal priming condition we found an object frequency effect (ADE20K object frequency computed from image datasets). Interestingly, the effect showed faster responses for both stimulus types when objects occur less frequently in image databases, which is opposite to the SUBTLEX-frequency effect. This latter finding might imply that recognition behavior can be more effective when objects are more distinct or diagnostic of a scene. In sum, both object and word recognition are faster when their concepts are often used in our language, but also, the distinctiveness of an object's appearance in the real world is essential to efficient access of semantic representations.

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Poster Session A > Object Recognition: Features and parts > Poster A68

‘Distinctiveness’ of parts in novel objects

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Henning Tiedemann[1] (henning-tiedemann@hotmail.de), Roland W Fleming[1,2]; [1]University of Giessen, [2]Center for Mind, Brain and Behavior (CMBB), University of Marburg and Justus Liebig University Giessen, Germany

When segmenting an object into its perceptual parts, certain parts appear more 'distinctive' than others. The trunk of an elephant, for example, is more distinctive than its tail, partly because few animals possess a trunk, whereas many have tails. These distinctive parts can be a vital clue for category membership. But even in novel objects, in which such real-world knowledge can not be applied, limbs vary in their distinctiveness, indicating that shape processing plays an important role in identifying the likely diagnostic features of objects. Which factors determine what makes a part distinctive? To investigate this, we showed 9 observers over 500 2D silhouettes composed of a large main body and two parts, differing in size, number of concavities, curvature characteristics and other features. They were then asked to indicate which of the two parts was the more 'distinctive'. Overall agreement between observers was well above chance at 83%, showing that observers consistently used similar strategies. They generally preferred parts with a larger area, more concavities, and where the contour curvature statistics deviated more from the main body. These results give us first insights into how we evaluate and make sense of novel objects and might explain how humans can generalize classes from a small number of samples.

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Investigating the Spatial Congruency Bias: The privileged role of location in visual processing is a product of development

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The spatial congruency bias refers to the phenomenon where people are more likely to judge two sequentially presented objects as being the same identity if they appear in the same location compared to in different locations (Golomb et al, 2014). Such a special role of spatial location in object identification has been demonstrated with diverse types of stimuli in previous research (e.g., abstract objects, colored squares, faces). However, the reasons why observers are prone to spatial location's influence on object-feature judgements remain unknown. We propose two theoretical types of mechanisms underlying the spatial congruency bias: vision-based and knowledge-based. According to the vision-based hypothesis, location is fundamental (and uniquely prioritized) in visual processing and its privileged role should be evident early in development. However, if the spatial congruency bias is knowledge-based, it should emerge during development as children acquire knowledge that objects in the same location are unlikely to change identity. To distinguish between these possibilities, we conducted a developmental study with young children. In three experiments of varying difficulty, adults or 5-year-old children were presented with two sequentially presented abstract objects and were asked to make same/different identity judgments. We replicated the robust spatial congruency bias in adults, but critically, 5-year-old children did not exhibit the bias despite exhibiting similar discrimination accuracy to the adults. The results suggest that spatial congruency bias is a product of development, perhaps resulting from learning that in the real world the same location generally cannot be occupied by different objects and that stable objects are unlikely to suddenly change their identities. Thus, the spatial congruency bias may reflect a robust example of how implicitly learned assumptions about the world can influence visual object recognition.

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Three-dimensional pose discrimination in natural images of humans

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Perceiving 3D structure in natural images is an immense computational challenge for the visual system. While many previous studies focused on the perception of rigid 3D objects, we applied a novel method on a common set of non-rigid objects—static images of the human body in the natural world. Perception of body structure is particularly challenging due to various joint articulations with different frequency of occurrence, and appearance variations from changes due to occlusion, clothing, lighting, and viewpoint. As a result, natural images vary in pose typicality and the amount of

information views provide to support body part parsing. We investigated (1) to what degree humans can interpret 3D body structure given viewpoint rotations about the vertical axis, and (2) to what extent this ability depends on a priori knowledge of 3D pose typicality and informativeness of viewpoints. Using a 2AFC pose matching task, we tested how well subjects were able to match a target natural pose image with one of two comparison, synthetic body images—one was rendered with the same 3D pose parameters as the target while the other was a distractor rendered with added noises on joint angles. Target natural images were drawn from the UP-3D dataset, whereas synthetic images were rendered with constant, predetermined clothing and lighting. Observers picked the synthetic pose which best matched the target despite changes in viewpoint about the vertical axis. We found that the ability to accurately match poses decreased with increasing differences between target and comparison viewpoints. When we grouped trials by typicality of underlying 3D poses and informativeness of viewpoints from natural images, we found that performance for typical poses was measurably better than atypical poses; however, we found no significant difference between informative and noninformative viewpoints. Our psychophysical results provide useful benchmarks for future model comparisons.

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Amodal statistical completion of occluded objects

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We can easily recognize objects even when they are occluded. Does our perception complete the occluded edges linearly or can it also employ more sophisticated extrapolation? To investigate this, we created displays where each occluded shape had two possible completions. These had identical contours in the unoccluded portion but differed in the occluded portion, such that one appeared to be the more likely shape behind the occluder, and the other was unlikely. Across two sets of such displays, we manipulated either the curvature of the occluded edge (‘curvature’ set) or the numerosity of edges (‘numerosity’ set). We asked whether perceptual dissimilarities, measured using visual search, between pairs of occluded shapes were correlated with those measured between pairs of likely or unlikely shapes. We observed that occluded shape dissimilarities were more correlated with the likely shape dissimilarities ($r = 0.85$ for ‘curvature’ and $r = 0.88$ for ‘numerosity’ sets, $p < 0.0005$) compared to unlikely shape dissimilarities ($r = 0.78$ for ‘curvature’ and $r = 0.67$ for ‘numerosity’ sets, $p < 0.0005$). Next, we asked whether similar patterns are present in deep neural networks trained for object recognition. In deep networks, the occluded shape representation matched better with the likely shape compared to the unlikely shape for the curvature set ($r = 0.92$ for likely shapes and $r = 0.81$ for unlikely shapes, $p < 0.0005$) but not for the numerosity set ($r = 0.77$ for likely shapes and $r = 0.77$ for unlikely shapes, $p < 0.0005$). Thus, deep neural networks failed to correctly extrapolate the statistics of the visible portion. Taken together, our results show that amodal completion is more complex than simple extrapolation of edges, relying on statistical properties to complete occluded objects.

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Asynchronous visual flicker alters perceived curvature

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According to the recently described ‘curvature blindness illusion’ (Takahashi, 2017), when changes in contrast polarity are introduced at minima/maxima along a sinusoid, the resulting waveform is perceived as triangular, or ‘zigzag,’ rather than curved. In the initial report, this effect obtained only for changes in contrast polarity, which appear, when placed appropriately, to prevent integration over the contour resulting in the percept of discrete segments of zero net curvature. However, accounts of dynamic binding through temporal synchrony suggest an alternate approach to generating this illusion. Elements of a display that occur concurrently tend to be grouped more easily than those that occur asynchronously, even when visual alternation rates fall in the gamma range (e.g. Elliott & Muller, 1998; Lu et al., 2006).

To the extent that temporal asynchrony facilitates segmentation, ‘curvature blindness’ may be also induced by visual flicker. Here, we investigated whether visual flicker is sufficient to induce ‘curvature blindness,’ and at which frequencies, if any, the illusion obtains. To this end, participants completed a 4AFC task in which they were presented with four distinctly segmented flickering waveforms (one of which was segmented at minima/maxima) and asked to choose the location of the ‘zigzag’ line. On experimental trials, all options were sinusoidal. On a small portion of catch trials, a triangle wave was substituted for one of the sinusoids in the display. To the extent that asynchronous visual flicker facilitates the ‘curvature blindness illusion,’ participants should label flickering curves that are segmented at maxima/minima as 'zigzag' more often than chance (25%). Across several experiments, the illusion emerged robustly at lower frequencies (between 5-20 Hz, peaking between 8-15 Hz), and decreased to chance as frequency was increased (up to 61 Hz), inconsistent with reports of induced grouping/segregation in the gamma range.

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Quantifying the latent semantic content of visual representations

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How does visual cortex extract semantic meaning from images? We hypothesize that visual cortex leverages the natural covariance between perceptual features and semantic properties and that it does so by representing perceptual features that support the efficient decoding of large numbers of semantic properties. Using convolutional neural networks (CNNs) and word embeddings (e.g., word2vec), we developed a statistical measure called semantic dimensionality that quantifies the number of language-derived semantic properties that can be decoded from a set of image-computable perceptual features. We combined this method with fMRI encoding models to estimate the semantic dimensionality of perceptual-feature tuning in the ventral visual stream. We first fit image-computable encoding models to object-evoked fMRI responses using mid-level features from pre-trained CNNs. Encoding-model performance reached the noise ceiling and thus fully accounted for explainable variance throughout much of occipitotemporal cortex. We then performed in silico experiments on the trained encoding models in regions of interest to estimate their semantic dimensionality. We found that encoding models of the ventral stream were tuned to subspaces of CNNs that yielded higher semantic dimensionality scores than other statistically-matched subspaces of the same CNNs, and we found that semantic dimensionality increased from low-level to high-level regions in the cortical visual hierarchy. Thus, the efficiency of decoding language-derived semantic properties from perceptual features increases along the ventral stream and far exceeds what would be expected by chance. In ongoing work, we are investigating whether tuning for semantic dimensionality develops separately or comes “for free” when optimizing for object recognition. Together, our approach provides a rigorous statistical assessment of the latent semantic content of perceptual feature representations, and, in doing so, it may help to resolve longstanding questions about the nature of perceptual and semantic tuning in visual cortex.

Poster Session A > Object Recognition: Features and parts > Poster A74

How do individuals who report psychotic-like experiences process visual illusions?

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Visual illusions offer the unique opportunity to examine the co-ordination of bottom-up and top-down processing by generating a predictable mismatch between sensory inputs and the subjective perception. As such, they represent useful tools in exploring anomalous perceptual experiences in clinical populations. Although still controversial, there is an overall trend in the literature suggesting an increased resistance to visual illusions in people with psychosis. Here, we quantified illusion susceptibility to a battery of 13 visual illusions in a clinical group of 25 young people reporting psychotic-like experiences and a control group of 74 participants. Depression, anxiety and stress levels were measured in both groups by means of a questionnaire, whereas frequency, appraisals and emotional responses to psychotic-like experiences were examined in the clinical group only by means of a semi-structured interview. In contrast to the general

finding of reduced illusion strength in those with psychosis, we observed that 10 out of 13 illusions tested generated greater effects in the clinical group compared to the control group. However, such a between-groups difference disappeared once depression, anxiety and stress levels were controlled for, suggesting that the overall increased susceptibility reported by the clinical group could be due to the severity of mental health problems, namely high levels of depression, anxiety and stress, associated with the psychotic-like experiences. Specifically, stress level turned out to be the best predictor of illusion strength in the clinical group. Results also revealed that illusion susceptibility in the clinical group was unrelated to anomalous experiences, depression and anxiety. We conclude that the tendency for the clinical group to exhibit greater vulnerability to illusions than the control group can be explained by increased levels of stress experienced by those reporting psychotic-like experiences. This enhanced susceptibility might suggest a distinct perceptual style biased towards top-down messages carrying prior expectations.

Poster Session A > Object Recognition: Features and parts > Poster A75

Mapping perceptual spaces of objects and low-level features

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The transformation of visual signals from elementary features into semantic content entails a qualitative change in the nature of the information that is represented. Elementary features (e.g., color or texture) form continua, while semantic representations (e.g., objects) are often categorical. To probe this process, we developed and implemented a psychophysical paradigm to characterize the geometry of visual representations at several stages of the transformation. We hypothesize that representing semantic information requires a different geometry from representing low-level features. In parallel experiments, stimuli were drawn from three domains: (1) the names of 37 familiar animals (from WordNet), (2) texturized but recognizable images of these animals, and (3) fully scrambled textures. In each experiment, subjects viewed displays consisting of one central reference stimulus with 8 surrounding stimuli and were asked to rank the surrounding stimuli in order of similarity to the central reference. This rank-order design yielded 5994 unique choice probabilities, and included trials to check for context-dependence, i.e., judgments of “Is A (the reference stimulus) more similar to B or to C?” in the presence of different surrounding stimuli. We found that choice probabilities were consistent across subjects and contexts (n=3 for (1), n=2 for (2), n=2 for (3)). We used multidimensional scaling to test Euclidean geometric models that could account for the similarity judgments. For all domains, the minimum number of dimensions needed to describe the perceptual space was greater than four. Although models of all the representations were similarly high-dimensional, preliminary results suggested that their geometric characteristics differed. Specifically, points in the semantic space (animal names) formed tight clusters and mostly were near the periphery, whereas in the two texture domains, the points were more evenly distributed throughout the space. These results suggest a qualitative difference between the geometry of representations of semantic information versus low-level features.

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Poster Session A > Object Recognition: Features and parts > Poster A76

Scene wheels: Measuring perception and memory of real-world scenes with a continuous stimulus space

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Precisely characterizing mental representations of visual experiences requires careful control of experimental stimuli. Recent work leveraging such stimulus control in continuous report paradigms have led to important insights; however, these findings are constrained to simple visual properties like colour and line orientation. There remains a critical methodological barrier to characterizing perceptual and mnemonic representations of realistic visual experiences. Here, we introduce a novel method to systematically control visual properties of natural scene stimuli. Using generative adversarial networks (GAN), a state-of-art deep learning technique for creating highly realistic synthetic images, we generated scene wheels in which continuously changing visual properties smoothly transition between meaningful realistic scenes. To validate the efficacy of scene wheels, we conducted a memory experiment in which participants reconstructed to-be-remembered scenes from the scene wheels. Reconstruction errors for these scenes resemble error

distributions observed in prior studies using simple stimulus properties. We additionally manipulated the radii of the wheels to parametrically control the similarity among the scenes in the wheels. Upon this manipulation, we found clear evidence that participants' memory performance systematically varied with the level of scene similarity. These findings suggest our novel approach to generate scene stimuli using a GAN not only allows for an unprecedented level of stimulus control for complex scene stimuli, but also that the GAN's latent spaces generating our scene wheels reflect fundamental representational spaces important for human scene perception and memory. Based on this level of control over the scene stimulus space, we expect that findings from using simple stimuli, such as colour wheels, will generalize to photo-realistic scenes, providing key insights into how we perceive and remember the real-world naturalistic environments that serves as the backdrop to our everyday experiences.

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Perceptual Organization 1

Poster Session A > Perceptual Organization 1 > Poster A81

Deep Neural Networks as a Computational Model for the Human Perception of Visual Symmetry

View Poster | Visit me in Gather.Town Dolphin Room on Saturday 8:00 am - 10:00 am EDT

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Background: Deep neural network (DNN) models developed for image classification have been suggested as biologically inspired models for visual processing (Yamins & DiCarlo, 2016). Here we apply a pre-trained visual DNN to model the mechanisms of symmetry perception in the human brain, where symmetry signals are found only in upper levels of the visual hierarchy (Tyler et al., 2005). Methods: To assess pure symmetry independent of recognizable objects, we used the standard ImageNet-trained VGG network model to compute the average L2 distance from zero symmetry for 500 random-dot symmetry images with one, two, and four axes of symmetry, relative to the L2 distances for zero-symmetry random-dot images. Results: The DNN L2 distances were 1.5 and 2 dB for one- and two- axis symmetry respectively, and up to 15 dB for four-axis symmetry. These effects were highly significant in the DNN upper layers (from layer fc6), but absent in the lower layers, except for 4-axis symmetry. We further found (1) a significant effect for partial symmetry down to 20%; (2) increasing symmetry effect with image size, saturating for larger images; (3) vertical axis predominance for 1-axis symmetry; (4) a surprising robustness of the DNN symmetry response to large gaps around the symmetry axes. In comparison, humans show no reduction in symmetry detection with gaps over very long ranges when scaled for cortical magnification (Tyler, 1996). Conclusions: These findings demonstrate effortless replication in a DNN of the human ability to perceive abstract symmetry, even in random-dot patterns devoid of recognizable objects, suggesting that symmetry is an emergent property of DNN networks trained to capture regularities in the natural environment. Although many visual objects incorporate structural symmetries, they are often distorted in natural images due to arbitrary viewpoints, making it remarkable that the network finds the symmetries so effectively with no symmetry training.

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Configural processing in humans and deep convolutional neural networks

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Background. Deep convolutional neural networks (DCNNs) trained to classify objects can perform at human levels and are predictive of brain response in both human and non-human primates. However, some studies suggest that DCNN models are less sensitive to global configural relationships than humans, relying instead on 'bags' of local features (Brendel & Bethge, 2019). Here we employ a novel method to compare human and DCNN reliance on configural features for object recognition. Methods. We constructed a dataset consisting of 640 ImageNet images from 8 object classes (80 images per class). We partitioned each of these images into square image blocks to create four levels of configural disruption: 1) No disruption - intact images; 2) Occlusion - alternate blocks painted mid-gray; 3) Scrambled - blocks randomly permuted; 4) Woven - alternate blocks replaced with random blocks from a distractor image of a different category. We then assessed human and VGG-16 object recognition performance at each level of disruption for 4x4, 8x8, 16x16, and 32x32 block partitions. Results. While block scrambling lowered both human and network performance, humans were much less impacted by occlusion than the network model. Also, while humans performed as well or better in the occlusion condition than in the scrambled condition, the network consistently performed better in the scrambled condition than the occlusion condition. In the woven condition, neither humans nor the network were able to reliably discriminate the coherent from the scrambled images, but we found that fine-tuning the network to report the class of the coherent image led to human levels of performance on the occlusion task. Implications. Both humans and the network were found to rely to some degree on configural processing. While humans may handle occlusion better than standard ImageNet-trained networks, training on woven imagery leads to human-like robustness to occlusion.

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Wedge patterns: A novel stimulus for studying mirror symmetry

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Studies of symmetry perception have generally used two stimulus types: figural and dot patterns. While figural patterns are more ecologically valid as they contain both position and orientation information consistent with a figure, dot patterns allow for tighter control of positional information in the absence of orientation. Here we designed a novel stimulus – a wedge pattern – made of centrally aligned but randomly-positioned wedges that is object-like but also allows for full randomization of element locations. Using a 2IFC task, we examined symmetry detection in wedge patterns made of different number of wedges (Experiment 1). The wedge patterns contained either two (red, green) or three (red, green, yellow) colours, with respectively 50% and 33% wedges arranged symmetrically, the remaining wedges being randomly positioned. Stimulus conditions were: segregated (i.e., position-symmetric wedges were of one colour), non-segregated (i.e., symmetric wedges were of all colours, in equal number), and anti-symmetric (i.e., symmetric wedges mismatched in colour). In Experiment 2, we directly compared performance for our wedge patterns alongside dot-patterns previously used by Gheorghiu et al. (2016, Sci Reports, 6, 29287) on an age-diverse sample of participants. In both experiments we used two perceptual conditions: without and with attention-to-colour. We found that (a) performance was independent of the number of wedges, in line with findings from dot patterns. (b) Attention to colour greatly increased accuracy for the segregated condition in both wedge and dot patterns, and significatly decreased it for anti-symmetric wedge-patterns, but not for dot patterns. (c) Accuracy was lower for older than younger adults (67% vs. 73%) in the no-attention condition but comparable in the attention-to-colour condition. In conclusion, symmetry seems to be processed in a very similar way for wedge and dot patterns. Stronger effects of attention to colour for wedge patterns are most likely due to their figural status.

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Efficient ensemble summaries are inversely related to visual crowding

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Visual crowding is the inability to perceive properly peripheral stimuli within clutter. Previous work has shown that crowding is affected by perceptual grouping: when the flankers do not group with the target, crowding decreases, leading to uncrowding. Typically, the grouping is driven by Gestalt-like effects. Here, we hypothesized that grouping by

statistical properties can affect crowding as well. Participants performed a Vernier acuity task in the periphery. Vernier stimuli were presented in isolation (baseline), surrounded by one square (crowding baseline), or within multi-element displays made of 35 flanker squares with varying tilt. We manipulated the tilt of each square according to different types of statistical distributions: one-peak narrow (low variance around a single mean), one-peak wide (larger variance), two-peak (two highly separable narrow distributions), and uniform. The tilt of the central square directly surrounding the Vernier target was fixed at either the mean or an outlier of the distribution. In a separate adjustment task, we measured participants' precision in estimating the mean tilt with the same distribution types. Our results show an inverse relationship between ensemble summaries and crowding: the larger the precision in statistical representations, the smaller the effect of crowding. Crowding was reduced when the central flanker corresponded to the mean of a distribution represented with higher precision (e.g., one-peak narrow), whereas it increased when it was an outlier. We discuss the role of statistical representations and the potential effect of other factors, such as the overall variance and the heterogeneity of flanker stimuli, in visual crowding.

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Ensemble representation of animacy could be based on mid-level visual features

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Recent studies propose that mid-level features could underlie animacy perception. Here we tested whether the ability to estimate ensemble summary statistics for animacy based on high or mid-level features. We used four types of animate and inanimate images (Long & Konkle, 2018): colorful images, greyscale images, silhouettes (contains only recognizable shapes), texforms (unrecognizable images, which preserve mid-level texture and shape information). In Exp.1 we asked participants to evaluate the animacy of single images and of sets of eight images of one type using a 10-point scale. In Exp.2, two sets of eight images of the same type were shown on the left and right parts of the screen and participants had to choose more animate one (2AFC task). We manipulated the animacy by changing the number of animate images in the set (Exp.1) or the number of animate images by which the two sets differed (Exp.2). In Exp.1, we found strong correlations between animacy ratings for sets and the number of animate objects in the set for all types of images. In Exp.2, we found that even when two sets differed only by one image the percentage of correct answers was higher than the guess rate. Despite weaker correlations for texfoms in Exp.1 and a lower percentage of the correct answer for texforms in Exp.2, participants were still able to report the mean animacy of the set. Also, participants categorize individual texforms as animate less confidently. We assume that the general deterioration of results for texforms in all tasks was connected with the noisier nature of texforms compared with other types of images. Thus, we suggest that the ensemble representation of animacy could be explained not only by high-level features but also by mid-level features, such as shape and texture.

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Does ensemble priming survive masking?

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In everyday life, we feel that our perception of the world is detailed, while our reports of it are poor (Simons & Chabris, 1999, Simons & Levin, 1997). Cohen, Dennett, and Kanwisher (2016) proposed that our rich perceptual experience can be explained by the ability of our visual system to extract ensemble statistics from groups of objects. Ensemble statistics computation overcomes many limits of perception - for instance, it is robust to inattention (Alvarez & Oliva, 2008). However, it is unknown whether ensemble statistics can be computed without awareness. In the present study, we tested the hypothesis that masked ensemble statistics can prime individual stimuli. The participants (n = 45) were presented with an ensemble of oriented gratings and asked to report whether a subsequently presented test grating was tilted to the right or to the left. The test grating had either the mean ensemble orientation, one of the members' orientations, or an explicit non-member orientation. The ensemble was backward and forward masked and we

manipulated the stimulus-onset asynchrony between the masks and the ensemble. In the aware condition, there was a 160 ms blank between the masks and the ensemble. In the unaware condition, there was no blank. Additionally, the participants completed two control tasks to assess whether the awareness manipulation was successful. The results show a main effect of the test orientation: the reaction times were lowest for the mean orientation, higher for member orientation, and highest for non-member orientation. The control tasks revealed that the ensemble was harder to detect in the 0 ms SOA condition, but it was not completely invisible. These results show that priming by masked ensembles is possible, yet it is unclear whether the priming effects stem from unconscious processing.

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The effect of grouping on numerosity judgment varies with the autism-spectrum personality traits, consistent with changes in local-global biases.

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Individuals with autism spectrum disorder or with non-clinical autistic tendencies are thought to have a perceptual style privileging local detail over global integration. Here we investigated whether the effect of grouping-induced response biases in numerosity judgments depends on autistic-like personality traits in typically developing adults. Perceived numerosity was measured by two alternative forced choice (2AFC), where participants reported which of two clouds of dots appeared more numerous, guessing when uncertain. In one presentation 40% of dots were grouped into “single items” (dumbbell-like shapes) by connecting pairs of neighboring dots with thin lines. Four different numerosities were tested (15, 25, 50 & 100) in separate sessions. As has been previously reported, at lower numerosities (≤50) all participants underestimated the numerosity of the stimuli with connected dots, by about 20%. The effect was much reduced (and insignificant) at N=100, where the dots were crowded. Importantly, the amount of bias at lower numerosities varied inversely with AQ, being greater for those with lower autistic traits ($r = 0.72$, $p < 0.001$, Bayes Factor = 126). As it is thought that connecting dots activates global mechanisms that cause dot-pairs to be processed as an integrated whole rather than as individual dots, the results suggest that these global grouping mechanisms may be weaker in individuals self-reporting high levels of autistic-like traits. The effects of grouping on extracting high-order information from the visual field may add an important piece to the puzzle of how visual processing differs in autism. We conclude that the preference for processing local over global elements in numerosity judgments varies along the autism continuum in the general population and might also be affected in individuals with ASD.

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Can multiple repetitions shield local processing from global interference?

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Hierarchical letters are large letters composed of smaller letters that form the global and local levels respectively. Our study uses these letters to study attentional control of multi-level item perception. A key aspect of attentional control is shielding, or the inhibition of irrelevant information (Neill, 1977). Studies show that irrelevant global information can interfere with local level processing, producing slower response times (RTs) for the local level (e.g., Navon, 1977). This indicates poor attentional control during local level processing. Interestingly, overall response times become faster when the relevant level is repeated, and especially with multiple repetitions (Lamb et al. 1998; Ward, 1982). Our study tests whether multiple repetitions can increase attentional control, by aiding the shielding of irrelevant global information. The experiment was organized into blocks, or runs, of seven trials; trials were identified by their sequential position within the run (e.g., the first trial is position one). At the beginning of each run, participants were given a target letter (A, E, G, K, U) and relevant level (global or local). Critical runs contained six congruent letters (e.g., large A made of smaller A’s) and one incongruent letter (e.g., large A made of smaller E’s). For each position, participants had to verify target letter presence at the relevant level. On the critical runs, every position in the run contained the target letter. Conditions varied based on whether positions two or six presented the incongruent letter, representing the single and multiple repetition conditions respectively. RTs for every position were recorded. For both global- and locally-focused runs, RTs became

faster with each repetition. However, there was no increase in attentional control for the local runs; equal amounts of global interference occurred at position two and position six. These results show that multiple repeated exposures did not improve attentional control.

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I see something you don’t see: The influence of the learning context on object correspondence.

View Poster | Visit me in Gather.Town Dolphin Room on Saturday 8:00 am - 10:00 am EDT

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Spatio-temporal as well as feature information play an important role for establishing object correspondence, i.e., determine how new information is integrated into existing object representations. It is unclear, however, how these two factors interact and why their influence can be found to be more or less strong. Here, we investigated if the learning context can influence this process. We used the Ternus display, an ambiguous apparent motion, in which three elements can be perceived as moving independently (element motion) or together as a group (group motion). Which percept is seen depends on how correspondence has been resolved. In a first phase we manipulated the learning context by showing two groups of participants different types of Ternus displays: for group one we manipulated the spatio-temporal information by modifying the interstimulus interval (ISI) between the Ternus elements, while for group two we kept the ISI constant and manipulated the feature information of the Ternus elements, using differently colored elements to bias the percept either towards group or element motion. In a second phase we showed both groups the same Ternus displays, for which the ISI as well as the feature bias was manipulated. Participants were asked in both phases to indicate whether they perceived element or group motion. If the learning context influences correspondence, we expected that participants would learn which factor is more meaningful to determine correspondence and thus to find different pattern of results for both groups in phase two, despite the displays being identical. In particular, for group one the ISI should have a stronger effect while for group two the feature bias should be stronger. This is exactly what we found, suggesting that which factor is more important for solving object correspondence – spatio-temporal or feature information – can be influenced by the learning context.

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Task set and instructions influence the relative weight of figural priors in figure-ground organization

View Poster | Visit me in Gather.Town Dolphin Room on Saturday 8:00 am - 10:00 am EDT

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In 100 years since the figure-ground phenomenon was first discussed by Rubin (1921), very little attention has been paid to the importance of task set and instructions on the outcome of figure-ground organization. Here we test whether changes in task set and instructions can alter the outcome of the cross-border competition between figural-priors that underlies figure-assignment. In figure-ground organization, the figure is defined as a region that is both “shaped” and “nearer”. Extremal edge (EE), a relative distance prior, has been established as a strong figural prior when the task is to report “which side is nearer?” In a within subject experiment using bipartite stimuli, EEs competed and cooperated with familiar-configuration, a shape prior for figure assignment. The experiment consisted of two blocks marked by the presence (Block-A) vs. absence (Block-B) of instructions emphasizing that familiar objects might be present. Within each block, two sub-blocks, one for each task set: “which side is shaped?” and “which side is nearer?” were counterbalanced across participants. Data from 24 participants for Block-A showed small but significant effects of familiar-configuration for displays sketching upright familiar objects, although “shaped-side” responses were predominantly determined by EEs. In Block-B, instructions regarding the possibility of perceiving familiar shapes were added. Now, although EE remained the dominant prior, the figure was perceived on the familiar-configuration side of the border on a significantly larger percentage of trials across all display types. With familiarity thus “primed”, effects of task set emerged when EE and familiar-configuration favored opposite sides as figure. Thus, changing instructions can modulate the weighing of figural priors for shape versus distance in figure assignment in a manner that interacts with task set. Moreover, we show that

the influence of familiar parts emerges in participants without MTL/PRC brain damage when instructions emphasize that familiar objects might be present.

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Can Pac-Man Change Your Perception? Semantic Priming affects the probability of experiencing the Kanizsa Illusion

View Poster | Visit me in Gather.Town Dolphin Room on Saturday 8:00 am - 10:00 am EDT

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The possible effects of cognition on perception are a matter of ongoing debate. An interesting case is visual illusions, which seem to be generally immune to knowledge about their illusory nature. In a series of five experiments, we examine if semantic priming can nevertheless impact such illusions, as a critical test to claims against cognitive effects on perception. We focused on the Kanizsa illusion, in which a shape is perceived via illusory contours. In Exp.1, a display (Kanizsa/no Kanizsa) was presented following a prime image that either promotes a semantic interpretation of the Kanizsa inducers (a Pac-Man game display, assumed to promote perceiving the Kanizsa inducers as Pac-Man characters), or does not (a scrambled version of the Pac-Man display). Participants reported which shape they saw in the Kanizsa display. Fewer detections of the Kanizsa shape were reported in the semantic Pac-Man group. In Exp.2, a non-Pac-Man related semantic prime was used, to negate the explanation that the effect stems from attentional engagement by any meaningful prime. There, no difference was found, suggesting that the effect is uniquely related to the semantic content of the Pac-Man display. Exp.3 and 4 importantly showed that the effect can also be obtained when using the word “PACMAN” as the semantic prime and a meaningless non-word as the non-semantic prime, demonstrating that the effect is independent of the prime’s presentation form. Finally, in Exp. 5, a reversed effect was found, where a semantic prime (the word "Triangle") was actually able to increase the likelihood of perceiving the Kanizsa triangle compared with a meaningless (non-word) or an incongruent ("Square") prime. Taken together, our results provide compelling and converging evidence for semantic, contextual effects on perceiving the illusory Kanizsa shape, hereby supporting claims of cognitive penetrability.

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The effect of proximity and continuity on amodal completion

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Due to the influence of COVID-19, the experiment was conducted online in laboratory training. This study examined the effects of proximity and continuity on amodal completion. This study focused on the effects of proximity and continuity as conditions under which two bars touched the top and bottom sides of a large rectangle were perceived to be connected as one bar behind the rectangle (6.0cm high, 12.0cm width). Actually, the perceived length was different for each participant. The position of the upper bar is fixed at 3.0 cm from the left side of the rectangle, and at 30 degrees. Five conditions were set for the angle and position of the lower bar based on the position and angle of the upper bar. The two bars were spatially closest to each other in the 0.0 cm condition. When the angle of the lower bar was 0.0 degrees, it was the same angle as the upper bar. The contact point of the lower bar with the rectangle was aligned with the upper bar in the 9.0 cm condition. 127 university students participated in this experiment. Some participants observed with their laptops and some with their smartphones. There was no difference in results by their devices. Each participant observed only one angular condition. The order in which the position conditions were presented was different for each angle condition. We classified the participants' descriptions into three categories whether the two bars appear to be connected as a single bar, to be separated into two bars, or to appear to be a single figure as a whole. 85% of participants reported a single bar in the 9.0 cm and 0.0 degrees condition. In terms of Gestalt grouping, it was tended to perceive them together in good continuity, not in proximity.

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Toward Quantifying Ambiguities in Artistic Images

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It has long been hypothesized that perceptual ambiguities play an important role in aesthetic experience: a work with some ambiguity engages a viewer more than one that does not. However, current frameworks for developing and testing such theories are limited by the availability of stimuli and data collection methods. We present an approach to measuring the perceptual ambiguity of a collection of images. Crowdworkers are asked to describe image content, and the variability of responses is summarized numerically. Experiments are performed using several classes of images: images created with Generative Adversarial Networks on Artbreeder.com, artwork datasets from previous studies on perceptual ambiguity, and photographs. Based on the hypothesis that perceptual processing is time-dependent, we measure responses after 500 ms and 3000 ms intervals. From these measurements, we find that several difference categories of ambiguity emerge. Moreover, our results address an intriguing paradox at the heart of modernist art history. Unrecognisable or intermediate images have been consistently celebrated for their aesthetic value by historians, critics, artists and members of the viewing public. Yet these very same images have also been attacked and ridiculed by other critics, artists, and members of the viewing public for the very reason that they are unrecognizable and indeterminate. How can we account for this paradox? Our results find that the raters in our experiments can be clustered into two categories: those that prefer ambiguous artworks, and those that prefer recognizable artworks.

Acknowledgements: Work performed during Adobe internship

Visual Search: Categories, cues

Poster Session A > Visual Search: Categories, cues > Poster A94

The role of category label in forming and functioning of a target template in visual search

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The visual search is guided by a target template held in a working memory (Duncan & Humphreys, 1989). In the real-world visual search tasks objects belong to the categories. For some of those categories we have labels, for others we have no labels. In this study we investigate the role of the categorical labels in target template's functioning during visual search performance. We suppose that the verbal label is tightly connected with the perceptual features of a particular category. So, the label is also included in a target template and helps to retain it in the working memory (through the phonological loop repetition). So, we hypothesized that in a verbal interference condition search time for targets with labels would be longer than for targets without labels. While in no interference condition a search time for targets with and without labels wouldn't be different. As the stimuli we used eight categories of a butterflies. Four of them were provided by the artificial meaningless labels. We used 2 × 3 × 2 mixed design with Category label (yes/no) and Set size (4, 6, 8 items) as within-group factors and Condition (verbal interference/no interference) as between-group factor. The categories were acquired on a first stage of experiment by a classification task. In the interference condition participants were asked to repeat a meaningless syllable (kyl) during visual search. Due to coronavirus we have collected data only for the no interference condition group (Twenty participants (14 women) aged 18-37 (M= 22.5)). Our results shows that Set size significantly influenced reaction time $F(2,38)=70.58$, $p< 0.0001$, while Target type and interaction of the factors were not significant. Those results indicate that our stimuli could be used for the experiment. Despite complexity of the stimuli none of those categories significantly different from others.

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Intertrial Effects in Visual Search Are Category Specific

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Visual search is frequently categorical, such as search for any member of the category ‘cup’. Categorical search templates must be formed from long-term knowledge based on exposure to category members. Recent work indicates that these templates are strongly biased toward recent experience. Specifically, feature regularities among recent exemplars from a category bias attention toward those features when searching for any category member. We hypothesized that a substantial portion of this effect derives from the last exemplar viewed. That is, we hypothesized that intertrial repetition effects can be category specific. Here, participants searched for an object cued by a category label (e.g., ‘cup’). Thirty-six categories were used, with one search trial per category in each of the 20 blocks. Target exemplars for each category appeared in one of two colors (e.g., cup targets were either grey or green, and car targets were red or white) and in one of two locations within the array. Target color and location within each category were randomly varied across blocks, creating four possible repetition conditions: color only, location only, both repeated, and neither repeated. Category repetitions were separated by an average of 36 trials, and thus any observed intertrial effects were necessarily based on retrieval from long-term memory. Both color and location repetition within a category facilitated visual search. In addition, these effects were broadly additive. Moreover, repetition effects were most pronounced in early blocks, with the effects decreasing across the experiment. In sum, the present results demonstrate 1) that intertrial effects are organized by object category, 2) that they can be based on retrieval from long-term memory, and 3), that they reflect both the properties of the most recently viewed exemplar and, because the effects diminished across the experiment, the accumulation of statistical regularities among multiple recent exemplars.

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Distractor suppression: Can top-down knowledge of non-target categorical information elicit rapid rejection?

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Most attempts to examine distractor suppression have restricted their distractor criteria to basic visual features (e.g. color, orientation). In two experiments, we tested whether distractor suppression extends to top-down categorical information. To do so, we created two categorical stimulus sets (real world images of teddy bears and butterflies) from which we derived silhouettes (preserving form information). To provide a ground truth that the silhouettes would induce traditional distractor suppression effects, in Experiment 1 we replicated the paradigm of Geng and DiQuattro (2010), using our categorical form silhouettes as the objects in place of simple shapes. Thirty-six participants indicated the location of an oriented bar embedded in an object silhouette (teddy bears or butterflies). Importantly, they were also told to actively suppress salient objects regardless of categorical information. We found that despite significantly fewer saccades towards the target on distractor-salient trials ($p < .001$), RTs were ~154ms faster compared to distractor-neutral trials ($p < .001$). This replicates prior findings and confirms that distractor suppression effects are broadly observable with our stimulus set. In Experiment 2, 79 participants were told to actively suppress either the teddy bear or butterfly object categories. The non-suppressed object category was considered the neutral object. This time, stimulus salience was held constant across all items and three trial types were presented: isolated (one object from the neutral category), neutral (two neutral objects), or suppress (1 neutral object and 1 object from the category to be suppressed). Critically, on trials where an item from the category to be suppressed was present, RTs were ~119ms faster than neutral trials ($p < .001$). This was driven by shorter dwell times on the suppressed distractors than neutral distractors ($p < .001$), providing evidence that top-down knowledge of categorical information can facilitate the rapid rejection of non-targets.

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The log rolls on: Hybrid search with same-category targets and distractors

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In a “hybrid search”, observers search for any of multiple targets stored in memory. Reaction time (RT) is typically a linear function of visual set size (VSS) and a logarithmic function of memory set size (MSS) (Wolfe, 2012). In previous experiments, targets and distractors were dissimilar objects taken from different categories, and, hence, they could be coarsely discriminated. Would logarithmic search through memory survive if targets and distractors were similar, thus requiring finer discrimination in memory? We compared search patterns when targets and distractors came from unrelated basic object categories to search when targets and distractors were different exemplars from the same category. Observers memorized 4-32 items and performed a pure memory search (Experiment 1: VSS=1, i.e., no visual search) or a hybrid search (Experiment 2: VSS=4 or 8). In both tasks, we found that search was slower and that RTxMSS functions were steeper in the "exemplar" search. However, the results were inconclusive regarding the shape of the RTxMSS function, because of insufficient VSS (Experiment 1) or a high error rate with large MSS (Experiment 2). In Experiment 3, to decrease the error rate, we employed a more engaging hybrid novelty search. On each trial, observers clicked on the one novel target among distractor objects, that had been seen at least once in previous trials (VSS=4). In this paradigm, MSS increases from trial to trial. 107 observers were tested for MSS=4-64. This task kept the error rate at a reasonable level (≤25% even at the highest MSS). Again, we found that the search among similar exemplars was slower than search among unrelated items. Critically, the shapes of the RTxMSS functions were logarithmic in both conditions. We conclude that the "logarithmic" character of memory search is robust and generalizes to the fine-resolution, same-category search.

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Scene grammar guidance affects both visual search and incidental object memory

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Previously acquired semantic and syntactic knowledge about scenes – so-called scene grammar – guides visual search and supports incidental encoding of objects. However, it is still unclear how scene grammar shapes our interactions with the environment and influences the resulting representations during natural behavior. To investigate this question, participants performed a repeated visual search task through a 3D virtual environment. They had to successively search for ten out of 20 possible target objects in ten realistic scenes. Crucially, half of the scenes were inverted to impede access to scene grammar guidance. Upright and inverted scenes were randomly interleaved. After searching, participants engaged in a surprise old/new object recognition task to assess incidental object memory. First results show that while participants searched descriptively longer in inverted scenes, learning between conditions did not differ. Using eye-tracking, we found that search initiation time was unaffected by scene inversion, but time to first target fixation and decision time were longer during search through inverted scenes. Importantly, time to first target fixation was affected by incidental gaze duration on the target object, but decision time was not. In the subsequent recognition task, we replicated previous findings observed in 2D according to which target objects were remembered substantially better than distractors. We found no main effect between search conditions, but an interaction effect. That is, targets searched in the upright condition were remembered better than targets of the inverted condition. Conversely, distractors were remembered better when they appeared in an inverted than in an upright scene. Moreover, decision time and incidental gaze durations on objects during search – but not search time – predicted memory performance in both conditions. Our findings demonstrate that during natural behavior scene grammar interacts with task relevance to guide search but results in a trade-off by affecting incidentally emerging object memories.

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Levels of visual clutter differentially impact search-based learning in naturalistic scenes.

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Humans spend much of their daily time in challenging and noisy environments. Frequently, this challenge takes the form of visual clutter (VC), i.e., the amount and organization of objects that fill up space. Previous studies have repeatedly demonstrated the deleterious effects of VC on visual search performance in artificial and naturalistic contexts. Recently, several qualities of the home environment, including VC, have been associated with performance in a long-term memory-guided attention task in children, therefore expanding the potential effects of VC to cognitive processes other than visual search. However, our knowledge about how visual clutter might influence long-term memory (LTM), in adults remains limited. To fill this gap, we investigated whether VC impacts the efficiency by which people search for, learn, and later recall the location of targets superimposed on low- and high-clutter naturalistic scenes. Over four learning blocks, participants had to search for a target embedded within each scene and were explicitly instructed to remember its location. After a 15-minute break, they completed a spatial memory task for the targets' location in the previously learned scenes. Results showed that participants became faster at detecting the target over the course of the learning blocks. Furthermore, in the learning blocks, they needed more time to detect the target within high vs. low-clutter scenes. In the spatial memory task, participants recalled the target location more accurately in high compared to low-clutter scenes. Yet, memory precision did not differ between the two clutter conditions. Interestingly, search time improvement during the learning phase (search slope) and the average search time across learning blocks were partially predictive of performance in high, but not in low, clutter scenes in the spatial memory task. These findings suggest that levels of VC differentially impact the way people search for and learn the location of targets in naturalistic settings.

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Is Contextual Cueing Unconscious? The Indirect Task Advantage in Implicit Learning

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We have recently shown that typical results from the unconscious priming paradigm suffer from serious methodological flaws that call into question the conclusions of many unconscious priming studies. Here, we describe a similar problem in the contextual cueing literature. In the priming paradigm, participants perform close to chance when directly attempting to identify or discriminate prime stimuli (direct task). Nevertheless, the same stimuli indirectly affect responses (e.g., priming effects on reaction times). From this pattern of results, researchers typically infer better sensitivity for the stimuli in the indirect than direct task, which is further interpreted as processing outside of conscious awareness. However, we have shown that this inference is flawed (Meyen et al., 2020). Similar to the priming paradigm, the contextual cueing paradigm follows the same logic: Participants show close to chance sensitivity in a direct task. In an indirect task, clear cueing effects on reaction times are found. This pattern of results is again used to infer better sensitivity in the indirect than direct task, which is then the basis for further-reaching inferences about unconscious processing. We generalized our methods to the typical contextual cueing paradigm (which often utilizes more response alternatives than the priming paradigm) and estimated the sensitivities of responses in the direct and indirect tasks based on the typically reported results. To do so, we present a model that relates participants' sensitivity in the direct task to the size of cueing effects in the indirect task. This allows us to compare sensitivities between the two tasks and test for a difference, which is required to make further inferences on unconscious processing. We reanalyzed multiple studies showing that some fail to provide evidence for better sensitivity in the indirect task, thereby calling into question the corresponding inferences about conscious/unconscious processing.

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Contextual information, visual working memory and inhibitory control in hybrid visual search

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In Hybrid Search (HS), observers are required to memorize potential targets and then identify their presence among various distractors. A hallmark of visual search is a linear dependence between response times (RTs) and visual set sizes (VSS), while memory search shows a logarithmic increase with the number of items in the memory set size (MSS). This has been interpreted on the basis of an efficient neural representation of remembered items, partially overcoming working memory (WM) limitations. However, the relationship between WM and search efficiency remains controversial. Moreover, although context plays a major role in real-world search, HS tasks have mostly used isolated stimuli. Here, we sought to examine the role of visual WM capacity in an HS task where potential targets changed in every trial. We also investigated the effects of contextual information in HS performance and studied the role of inhibitory control (IC) in search termination. In online experiments, 110 participants performed a HS task, a change-detection task to assess visual WM, and a go/no-go task. Concurrent EEG and eye movement recordings were measured in a separate sample to investigate the interplay between search, WM, and neural oscillations. We show that, in target-present trials, the main hallmarks of HS remain present. Consistent with recent findings, contextual information facilitated visual search (Vo & Wolfe, 2016) but not memory search (Boettcher et al., 2018). Individual differences in visual WM did not predict HS performance. In target-absent trials, context played a major role and HS performance could be predicted by IC, showing a direct link between inhibition and search termination. Finally, we used the behavioural findings to study neurophysiological signatures of HS. Whereas this study adds ecological validity to well established RT signatures of HS, it also provides insights into the effects of WM and context on HS efficiency and search termination.

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A factorial analysis of contextual cueing reveals the primacy of local context surrounding the target

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Visual search performance can be facilitated by incidentally learned associations between contextual regularities and target locations within repeated displays, effect known as contextual cueing (CC). Robust CC effect has been found in numerous studies, but the exact mechanisms underlying CC are still not well understood. Here, we investigated the factors that best account for differential CC effects across repeated stimulus configurations. Twenty-three participants searched a T-shape target among L-shape distractors and reported the target’s orientation in a standard CC task. We performed a principal component analysis on 15 variables with a sample of N = 276 pseudo-random configurations to explore the factor structure of the repeated configurations. The 15 variables characterized information about inter-stimulus distance (Mean and SD target-distractor distance, Mean and SD distance between stimuli), target position (X and Y coordinates, N boarder tiles around the target), and target-distractor proximity and similarity (N neighbors, N neighbors differing from the target’s orientation, N neighbors differing from the target’s color, N different colors among neighbors, each variable considered either as a function of direct adjacency to the target or within the target’s quadrant). Based on parallel analysis, we extracted three factors, accounting for 61% of the total explained variance. A factor analysis based on Oblimin rotation to account for the intercorrelation between factors allowed us to retain 13 variables showing high loadings (> 0.40) for one of the three factors. The three factors in their order of importance could be expressed as adjacent neighborhood, inter-stimulus distance, and quadrant neighborhood. The regression model

selection for the factors onto CC effects configuration-by-configuration indicated that the best-fitting model with the lowest AIC retained information about the target's quadrant neighborhood. These results support the importance of local context in the differential effect of CC across spatial configurations.

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Search guidance from the relative arrangement between objects

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Objects do not exist in isolation; they exist in relation to each other. Recognizing that a printed Journal of Vision article is below a desk lamp is thought to require a focal shift of attention between objects (Franconeri, et al., 2012). Relatedly, target object pairs produce highly inefficient search slopes when distractors only differ by their relative arrangement (X above Y, vs. X below Y), suggesting a serial process and no attentional guidance (Logan, 1994). Rather than searching for an article below a lamp, observers might search for the features of an article and/or a lamp, then check their relative arrangement. We tested these hypotheses across two experiments that recorded eye movements and used previewed random pairs of trial-unique real-world objects. Experiment 1 asked participants to search for object pairs that only differed from distractors in their relative arrangement, preventing target-feature guidance from individual objects; guidance would rather require a holistic representation that captures the relative arrangement. Experiment 2 asked participants to search for target pairs among heterogeneous pairs of distractors, which allows target-feature guidance from individual objects. The targets relative arrangement was swapped on half of the trials (indicating target absence). Above chance search guidance in Experiment 1, and significantly more guidance for matched relative to swapped targets in Experiment 2, argues for small but significant search guidance based on the relative arrangement of objects (operationalized as the proportion of trials where the target pair was fixated first, and the number of distractors fixated before the target; all $p < .05$). We conclude that the computation of relative object arrangement may not be strictly serial, and that it is possible to extract and use a relative-object-arrangement feature to guide search. Future work will explore related features that generate small amounts of guidance in other highly inefficient searches.

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Repetition number, but not spacing, affects spatial context learning

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One can more quickly find a visual search target when it appears in a previously-encountered context than when it appears in a novel context. Previous studies suggest that this Contextual Cueing effect represents a form of associative learning of the relationship between repeated contexts and the target's location. However, it is unclear what kind of training schedule is optimal for acquisition and maintenance of Contextual Cueing. Specifically, researchers have yet to determine whether the number of repetitions and the relative spacing of repetitions influence the magnitude and persistence of the reaction time advantage for repeated contexts, relative to novel contexts. To explore this, we compared three training schedules in a within-subjects design. Participants searched for a letter T among Ls and indicated the T's orientation using arrow keys. Thirty-six displays repeated throughout the 24 training blocks, with 12 displays appearing once in each training block (standard schedule; 24 repetitions total); 12 appearing once in each of the first seven blocks and once in the last training block (massed schedule; eight repetitions total); and 12 appearing in blocks 1, 2, 4, 6, 12, 16, 20, and 24 (spaced schedule; eight repetitions total). In a subsequent testing phase, all displays appeared once in each of the four testing blocks, along with 36 novel displays. The only training schedule that yielded a reliably larger Contextual Cueing effect than others was the standard schedule with the most repetitions. This pattern of results (Experiment 1, N = 32) persisted when participants were told in advance that displays would repeat (Experiment 2, N = 31). It also held when participants were tested 24 hours after training (Experiment 3, N = 32). Thus, the number of repetitions, but not the spacing of the repetitions, modulates the associative learning that occurs in Contextual Cueing.

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Different spatial transfer of high-level and low-level priming of pop-out with the double-drift illusion.

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Priming in pop-out search reduces reaction time when the target’s feature is repeated in successive trials (Maljkovic & Nakayama, VR 1994). The level at which this effect occurs has been a long-standing debate (e.g., Kristjánsson, VR 2006; Huang et al., M&C 2004). In the double-drift stimulus, a target patch moves in one direction while its internal 1/f noise drifts in the orthogonal direction, causing the perceived path to deviate dramatically from the physical path. Previous studies showed that the perceived and physical paths are represented at different stages of the visual hierarchy (Liu et al., 2020); moreover, pop-out is seen for a perceived oddball in the presence of conflicting physical paths, but not for a physical oddball in the presence of conflicting perceived paths (Özkan et al., AP&P, 2020). Thus, double-drift trajectories provide a critical test for the level of processing and the mechanism underlying priming in visual search by examining whether repeated physical and/or perceived paths induced priming. In each trial, we presented two arrays of 8 moving patches, separated by 200 ms. Each array included a target that is both a perceived and a physical oddball. The oddballs in the first and the second arrays could either share perceived or physical directions or both or none. Each item had a red or green dot superimposed on its center. Participants reported the color of the target's dot (50% probability). Repetition of a perceived pop-out feature produced significant priming that transferred to all locations. Repetition of a physical pop-out feature also produced significant priming, although of a lesser magnitude, but, importantly, only to positions within the same hemifield (left vs right). Our findings suggest that priming occurs in multiple stages of the visual hierarchy while the spatially global effects arise only for late representations.

Acknowledgements: NSF EPSCoR Award #1632738

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Perceptual and categorical similarity in visual search for multiple targets

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Subsequent search misses (SSM) effect is the decrease in accuracy of second target detection after finding the first target in visual search task. One of the SSM explanations considers that searchers are likely to become biased towards targets that share similar features with the initially found target. One study (Biggs et al., 2015) revealed the role of both perceptual and conceptual similarity in SSM errors. The main focus of the current study was to experimentally separate categorical and perceptual similarity in order to discover their individual contribution to SSM. Participants' task was to search for targets of vertical orientation among differently oriented distracters. Targets and distracters were uppercase and lowercase letters of Russian alphabet. On each trial, it could be one, two or no targets. In dual-target trials, targets could have both perceptual and categorical similarity, only perceptual similarity, only categorical similarity, or neither perceptual, nor categorical similarity. Perceptual similarity was manipulated by color (same or different), categorical similarity was manipulated by letter identity (targets could be the same letter - one was uppercase and another was lowercase, or different letters). Accuracy and reaction time were analyzed. Two-way rmANOVA tested the effects of perceptual and categorical similarity. Dual-target trials were also compared to matched single-target displays. Categorical similarity had a significant effect on second target detection: categorically similar second targets were found better as compared to categorically dissimilar ones. No main effect of perceptual similarity was found in the second target detection accuracy, except the case of categorically dissimilar targets. SSM effect was observed for perceptually, but not categorically similar targets and for dissimilar targets. For reaction time, categorical and perceptual similarity

effects were significant. Overall, both categorical and perceptual similarity had the impact on SSM errors, and the effect of categorical similarity revealed its superiority over the perceptual similarity.

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Binocular Vision: Rivalry and competition

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Nasal visual field of origin contributes to interocular competition strength

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During binocular rivalry (BR), perceptual dominance alternates between the inputs of the eyes, meaning that (at any time) the non-dominating input is suppressed, despite being projected on a retina. It has been proposed that BR is the result of interocular competition (IOC), where the input that 'wins' the competition becomes the dominant percept. Both top-down factors (e.g., attention, working memory content) and bottom-up factors (e.g., saliency, eye dominance) have been shown to affect IOC. One factor has remained largely disregarded, however: the input's visual field of origin. The lack of attention to this factor is surprising, since the visual field of origin is known to affect performance in various contexts outside of BR. Exploratory analyses on previously gathered data using a breaking continuous flash suppression (b-CFS) paradigm suggested that nasally presented targets (i.e., presented in the nasal visual hemifield (VHF)) broke through suppression faster than temporally presented targets. We confirmed this exploratory observation in a reanalysis of five independent b-CFS datasets. Strikingly, we found that the effect of VHF was even larger (by 25%) than the well-established effect of eye dominance, as measured by response time differences in the b-CFS paradigm. Importantly, the magnitude of the VHF effect depended on the strength of IOC, both within-observers (recessive > dominant eye), and across-observers (weak > strong eye-dominance). These findings show that the VHF effect reported here is specific to IOC, rather than reflecting a generic visual field anisotropy. Lastly, we simulated 10.000 datasets to show that our findings did not spuriously emerge from our analysis pipeline. Taken together, we demonstrate a substantial advantage for visual input from the nasal VHF during IOC. These findings have broad implications for augmented/virtual reality applications and yield important methodological considerations for researchers utilizing IOC-based paradigms to investigate the contents and functions of human consciousness.

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Examining Eye- and Stimulus-Level Competition during Rivalry Onset

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Introduction: Many inferences about the neural mechanisms of binocular rivalry have been made by studying the relationship between stimulus properties and sustained rivalry oscillations (Brascamp et al., 2015; Levelt, 1965). Yet, little is known about the dynamics of rivalry onset, the time leading up to the initiation of perceptual competition during rivalry, which is thought to be independent from ongoing rivalry oscillations (Carter & Cavanagh, 2007). Here, we examined how both eye- and stimulus-level competition govern the dynamics of rivalry onset by quantifying individual ocular dominance magnitude and varying the degrees of monocular stimuli disparity during rivalry. Methods: 9 adults participated in a binocular rivalry experiment which was composed of 78 trials, 8-second trials (6 practice trials). On each trial, disparate Gabor patches were presented to each eye via a head-mounted virtual reality display. Orientation disparity between the two stimuli varied across trials (60, 90, & 120 degrees). Using a keypad, participants continuously reported their percept (right-tilted, left-tilted, or mixed). Eye dominance magnitude was computed as the difference between the number of trials with dominant vs. non-dominant eye breakthroughs. Results: We found that eye dominance was a significant predictor of average rivalry onset latency (β= -0.032, p=0.019), where individuals with greater eye dominance showed shorter latencies to rivalry onset. We also observed that stimulus orientation disparity was a

significant predictor of rivalry onset latency (F(2)=18.4, p=0.026), where smaller stimulus disparities predicted longer rivalry onset latencies. Post-hoc tests indicated significant differences between 120- and 90-degrees disparities (p=0.024). However, the 90-degrees condition (M=1.80, SD=1.62) did not differ from the other two. Conclusion: Together, our results demonstrate that competition at both eye- and stimulus-level contribute to the speed of perceptual resolution during rivalry onset. These results add to our mechanistic understanding of the phenomenon of rivalry onset.

Poster Session A > Binocular Vision: Rivalry and competition > Poster A110

InFoRM (Indicate-Follow-Replay-Me) Rivalry: A novel method to measure and analyze perceptual experience

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Binocular rivalry has been measured for over 100 years by Alternative-Forced-Choice(AFC)-tasks that monitor 2-4 perceptual states(exclusive OS/OD and piecemeal/superimposition) to provide insights into the dynamics of visual consciousness and excitation-inhibition in neurological impairments. These methods lack: validated individual introspection, dynamic transition-measurements between-within experimenter-defined AFC-states, resolution within mixed states, weighted transition-probabilities. We introduce InFoRM(Indicate-Follow-Replay-Me) Rivalry, an assumption-free 4-phase-method that dynamically tracks and validates perceptual experiences, allowing novel insights into rivalry dynamics. 25 normally-sighted participants completed InFoRM for 3 contrast conditions using 2c/° ±45° sine-gratings in 2°apertures. A stereoscopic display was used to present binocular-non-rivaling and dichoptic-rivaling stimuli, leaving naïve subjects condition-blinded. Participants moved a 60Hz-joystick to actively control the physical stimuli or to provide a continuous output of perceptual experience. Perceptual-state-space was controlled with thresholded band-pass filtered noise: the vertical joystick axis mapped fPeak(# areas); the horizontal axis mapped threshold(proportion for each image). During Indicate-Me, participants explored the stimulus-space for 60sec, moving the joystick to modify binocular-non-rivaling stimuli in real-time and simulate six canonical rivalry states. During Follow-Me, participants matched perceptual reports for physically changing binocular-non-rivaling-stimuli in four author-created rivalry-trials and four self-generated trials illustrating canonical rivalry states from Indicate-Me. During Rival-Me, participants reported their perception during eight 60sec-trials of dichoptic-rivalry. During Replay-Me, participants' responses during the eight Rival-Me dichoptic-trials were used to generate physically changing binocular stimuli, which validated their individual perceptual-state-space. The self-generated Follow-Me responses were classified as 6AFC classic responses, which resulted in findings comparable with previous research. However, the underlying perceptual states were continuously varying with idiosyncratic experiences of mixed percepts' size and shape, that we analyzed with weighted Markov-chains. Rivalry-speed and-velocity were also analyzed. InFoRM Rivalry therefore provides an unbiased, validated estimate of dynamic, personalized perceptual-state-spaces and promises to be a novel tool for both basic science of visual consciousness and clinical research of interocular suppression.

Poster Session A > Binocular Vision: Rivalry and competition > Poster A111

Binocular rivalry perceptual memory in schizophrenia and in acute ayahuasca administration

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Background: Working memory impairment is a core cognitive sign of schizophrenia. Acute administration of ayahuasca, a psychedelic agent that partially models psychosis, also impairs working memory. Binocular rivalry switching rate is slower with schizophrenia and slower with ayahuasca administration, but perceptual memory for binocular rivalry has not yet been investigated in these contexts. In 2000-2002, we studied binocular rivalry switching in patients with schizophrenia (n=23, taking maintenance doses of anti-psychotics), in healthy controls (n=18, matched for age, gender, and parental education), and in other healthy volunteers who ingested ayahuasca (n=10), tested on-drug and retested post-washout. Objective: Reanalyze these 2000-2002 data for whether recent binocular rivalry response history influences response duration probabilities, indicating perceptual memory. Binocular rivalry and working memory tasks are so cognitively dissimilar that eliciting recalled content, as is done to index working memory, may be insensitive for

indexing rivalry memory. Methods: Sampling distribution variances of response duration subsample means, as a function of subsample size, were compared in participant-produced order (preserving history) or in shuffled order (scrambling history, response distributions unchanged). This tests whether participants produce non-random duration sequences that shuffling disrupts. Results: On-drug, order shuffling had no effect (paired samples Wilcoxin Signed-Rank Z=0.55, p=ns), thus not indicating perceptual memory. Post-washout, the same individuals showed perceptual memory via variances calculated using different orders differing significantly (Z=1.82, p< .04). Perceptual memory was likewise found for schizophrenia (Z=2.61, p< .01) and for controls (Z=3.40, p< .001). Discussion: Response history had no detectable influence on response durations while affected by ayahuasca but the influence of binocular rivalry perceptual memory returned post-washout. Patients with schizophrenia had significant perceptual memory but with 0.79 smaller effect size (Cohen's d) than that found for controls. How ayahuasca and schizophrenia degrade both perceptual memory and working memory performances is not presently known. Further investigation appears warranted.

Acknowledgements: Published data presently re-analyzed were obtained with support by a VA Merit Review Grant to the late John M. Kuldau and by a Stanley Foundation grant to the late John D. Pettigrew.

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Interocular difference detection is facilitated as well as suppressed by surround masks

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Interocular (between-eye) contrast differences (ICDs) elicit an impression of lustre, a cue to their detection. Recently Kingdom, Jennings & Georgeson (JOV, 18(5):9, 2018) provided evidence that ICD detection is an adaptable dimension of vision, in keeping with the idea that ICDs are detected by a dedicated binocular differencing channel, termed B-. Here we study the properties of the putative channel using surround masking rather than adaptation. Observers were required to detect ICDs in the form of interocular phase differences between horizontally-oriented 0.5 cpd test luminance gratings in a circular 2 deg diameter window. The test gratings were surrounded by 0.5 cpd horizontally-oriented luminance mask gratings that were interocularly either in-phase or anti-phase. ICD thresholds for a 10% contrast test increased with the contrast of the anti-phase surround, indicating surround suppression. With the in-phase surrounds ICD thresholds decreased gradually with contrast, indicating surround facilitation. The results are consistent with a B- channel that is subject to inhibition from surrounds containing interocular differences but which benefits from surrounds that are interocularly matched, suggestive of a mechanism that plays a role in perceptually segregating regions with and without interocular differences.

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Measuring the monocular interocular delay in amblyopia

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Amblyopes suffers from interocular asynchrony due to an interocular delay which could either affect the amblyopic or the fellow eye. Most methods to measure this interocular delay can be used either on mild or strong amblyopes, but rarely on both. In this study, we adapted a paradigm recently developed by Burge and Cormack (2020), to measure the interocular delay on a large span of amblyopes. This method offers the advantage to be monocular, therefore allowing a measurement in a large range of amblyopes, regardless of whether they have binocular fusion. It is based on the concept of continuous psychophysics. The task of the subject is simply to track a moving bar on a computer screen with the computer mouse. Amblyopic and control participants were tested monocularly with each eye, as well as binocularly. The delay for each eye compared to the binocular delay could be measured at a millisecond level of precision. At the group level, we observed a delay in the processing time of the amblyopic eye. However, in some mild amblyopes, the delay was observed in their fellow eye. To conclude, we successfully applied this new tracking method to measure the interocular delay in the amblyopic population. This method is very promising as it can be used for a wide variety of participants and could therefore be applied to clinical conditions.

Acknowledgements: Supported by a Canadian Institutes of Health Research Grant CCI-125686.

Face Perception: Individual differences 1

Poster Session A > Face Perception: Individual differences 1 > Poster A121

Super-Recognizers: 70 cases identified with a novel diagnostic framework

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Over the past decade, the domain of face identity processing has seen a surging interest in inter-individual differences, alongside a focus on individuals with superior skills — so-called Super-Recognizers (SRs; Russell et al., 2009; Ramon et al., 2019). Their study can provide valuable insights into brain-behavior relationships and advance our understanding of neural functioning. Despite a decade of research, and similarly to the field of developmental prosopagnosia, a consensus on diagnostic criteria for SR identification is lacking. Consequently, SRs are currently identified either inconsistently, via undocumented collections of tests, or via single (oftentimes suboptimal) tests. This state of the field has two major implications. Firstly, our scientific understanding of SRs will remain at best limited due to inclusion of false-positive "SR" cases. Secondly, the needs of international security agencies interested in deploying SRs for real-life identity verification are unlikely to be met. To counteract these issues, I suggest the following action points. Firstly, based on recent work suggesting novel and challenging tests of face cognition (Fysh et al., 2020; Stacchi et al., 2020), I have developed a novel diagnostic framework for reliable SR identification (Ramon, 2021). Its criteria are currently being used to screen the Berlin State Police's >18K employees prior to SR identification via collaboratively developed, bespoke applied testing procedures involving authentic police material (Ramon & Rjosk, 2021). Secondly, I describe how the growing cohort of currently 70 SR individuals identified using the framework is being studied in-depth using behavioral methods, psychophysics, eye-tracking, and neuroimaging (e.g., Linka et al., 2021; Nador et al., 2021). Finally, I stress the need for transparent and consistent reporting of SR individuals across studies to exploit their informative value of this unique population to advance our understanding of brain functioning.

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Poster Session A > Face Perception: Individual differences 1 > Poster A122

When better is worse: Better face recognizers are more susceptible to the effect of face masks

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Face masks became the first line of defense in the effort to minimize the effects of the COVID-19 pandemic. We demonstrated that face masks modulate holistic face processing, with participants engaging in a local, feature-based processing style and showing worse face perception for masked faces (Freud et al., 2020). An outstanding question is whether there are individual differences in the effect of face masks on face perception. Previous studies have demonstrated that better face recognition abilities are associated with a greater degree of holistic processing (Wang et al., 2012). Given the detrimental effect of masks on holistic processing, we predicted that individuals who have better face recognition abilities would be more adversely affected by the inclusion of masks. To examine this hypothesis, we tested face perception using the Cambridge Face Memory Test (CFMT) in 179 participants. The extended CFMT is comprised of four phases that progress in difficulty, for a total of 102 trials. Participants were asked to learn to recognize six target faces from three different viewpoints (targets shown for 3s each) and were subsequently tested on their face recognition in a 3-AFC task. Participants completed the CFMT twice, with masked faces and non-masked faces. In line with our prior work, a substantial decrease in performance was found for masked faces. Importantly, participants with better face recognition abilities showed higher susceptibility to the effect of face masks compared to lower-performing individuals. Particularly, data were binned into five bins based on performance with non-mask faces. The mask effect linearly increased from bin 1 (lowest performance, mask effect = 1%) to bin 5 (highest performance, mask effect = 15%). Taken together, our results show that face masks disrupt face perception and that the severity of this disruption depends in part on individual differences along the degree of holistic processing of faces.

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Poster Session A > Face Perception: Individual differences 1 > Poster A123

Consistency — a neglected marker of superior face processing

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So-called super-recognizers (SRs) possess exceptional face processing abilities. Yet, the factors underlying their heightened abilities remain unknown, owing to overreliance on underspecified diagnostic tests. In general, these employ simple accuracy measures, yielding at best piecemeal correlations between various sub-processes. Given the inter- and intra-personal heterogeneity across sub-processes, we argue here—across four experiments in two independent studies—that consistency of face processing distinguishes superior face cognition abilities. In Study 1, we analysed sensitivity to spatial frequency content of face stimuli across viewing distances, bandwidths and orientations in two one-to-ten face matching experiments for 11 SRs and 31 normal observers. The first simulated variations in viewing distance systematically; the second instead varied the bandwidths of horizontal and vertical spatial frequency content separately (c.f., Nador et al., 2021). Across these experiments, we find that controls and SRs are sensitive to the same range of identity-diagnostic information (i.e., with equal absolute thresholds), which are, however, exploited more consistently by SRs (i.e., with different psychometric slopes). In Study 2, we analysed sensitivity to face memorability in two old/new recognition experiments among 10 SRs and 22 normal observers, by adapting a split-half “with-or-without-you” resampling technique for pattern analysis (Nador et al., 2020). In Experiment 1, recognition performance was solicited surreptitiously: after completing an initial gender categorization task, observers’ recall of those same images (among novel probes) was tested. In Experiment 2, observers explicitly memorized a set of faces, and were subsequently tested on different views of the same facial identities (again, among novel probes). Here, we find that SRs’ recall performance is more consistent between image- and identity-based memorability. Overall, our results suggest that intra-observer consistency is a critical behavioral marker for identification of individuals with superior face processing skill.

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Poster Session A > Face Perception: Individual differences 1 > Poster A124

Individual differences in face perception: Development and validation of the Oxford Face Matching Test (OFMT)

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Tests of face processing are commonly designed to identify individuals performing outside of the typical range; either developmental prosopagnosics or super recognisers. Here we describe the development of the Oxford Face Matching Test (OFMT), designed to identify individual differences in face matching performance across the full range of abilities, from prosopagnosia and autism, through the range of typical performance, to super recognisers. The OFMT is uniquely designed to span the entirety of human perceptual difficulty space through use of facial recognition algorithms in deriving item similarity ratings. In a series of six studies, the OFMT is shown to be sensitive to individual differences in the typical population, reliable and stable over time, and sensitive to atypical group performance in developmental prosopagnosia,

autism, and super recognition. In Studies 1 (N=45) and 2 (N=106), the task is validated for in-person and online administration with a wide range of reported scores (mean=74.1%[59.5-84.0%] in Study 1; mean=72.9%[52.0-86.0%] in Study 2) and moderate correlations with existing gold-standard face processing measures, such as the CFMT (r=0.32* and r=0.34*, respectively). In Study 3 (N=72), the OFMT is shown to have high reliability following a 2-week delay (r=0.75*), comparable to reliability indices for similar tasks (CFMT: 0.67*, GFMT: 0.77*). In Studies 4 (N=62), 5 (N=64), and 6 (N=61), the OFMT is shown to be sensitive to differences between matched control groups and, respectively, developmental prosopagnosics (t(58)=-5.78, p<.001), super recognizers (t(62)=4.88, p<.005), and autistic participants (t(59)=-2.94, p=.005). These results indicate that the OFMT is a reliable and valid measure of face perception that can be meaningfully applied to participants across the spectrum of abilities. It shows sensitivity to individual differences across the population with a wide range of performances and no floor or ceiling performance. Future directions in refining our understanding of face matching mechanisms across populations are discussed.

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Face memory and source memory abilities correlate in typical perceivers.

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Face ‘Superrecognisers’ not only recognise faces seen long before, but appear to remember where they met, at least anecdotally. It is not theoretically obvious that good face memory should be associated with good source memory (e.g., for specific locations). We examined this question in two experiments. In Experiment 1, typical perceivers (n=78) were shown 6 face images of the same sex, sequentially, each superimposed on a different background image. At test, they were shown 6 new images of the study faces and 6 unseen faces and asked to make an old/new judgement. If they said old, they were presented with four of the backgrounds and asked to pick the one the face was on at study. They were then asked to click on the specific location they thought the face was on. The process was then repeated, using faces of the opposite sex and new backgrounds. There was a correlation of .53 between d’ (sensitivity) for face memory and the proportion of faces for which the backgrounds were also correctly remembered, and a correlation of -.36 between d’ and error in locating the face, in pixels. In Experiment 2, we removed the cue of the background image at test. Typical perceivers (n=66) were shown 10 faces at study, each presented on one of 10 different backgrounds which could be grouped by type (office, bedroom, bathroom, etc.). For each of the 20 test images reported as old, a word list of the possible location types was presented for a decision about the background at study. The process was again repeated using the opposite sex of faces. The correlation between d’ and the proportion of correct types of background chosen was .62, replicating the result from Experiment 1. Our data suggest a strong correlation between face and source memory in typical perceivers.

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Poster Session A > Face Perception: Individual differences 1 > Poster A126

Response times in an old/new face recognition test provide an objective measure of face memory deficits in developmental prosopagnosia

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The nature of face recognition memory deficits in developmental prosopagnosia (DP) remains to be fully characterized. Previously, a dual process analysis of confidence ratings during face recognition showed that, compared to controls, DPs have deficient recollection (all-or-none recognition with context) but intact familiarity (feeling of knowing) (Stumps et al., 2020). Since confidence ratings are subjective, response times (RTs) may provide a complementary, objective measure of DPs’ memory deficits. To test this possibility, 30 DPs and 30 controls performed an old/new face recognition

task where they studied 60 faces, each shown for 1.5 seconds, twice. At test, 60 new (lure) faces were interspersed with 60 old (target) faces, and participants made old/new judgments with confidence ratings (confident/somewhat sure/guessing), and RTs were recorded. For all participants, RTs differed across confidence ratings, displaying the standard pattern of fastest RTs to high confidence and slowest RTs to low confidence responses. Controls' cumulative distribution functions (CDFs) showed markedly faster RTs for correct target responses than for correct lure responses. DPs' correct response CDFs did not differ from each other or from control lure responses, suggesting that controls had access to a target-present signal that DPs lacked. Using RT Receiver Operating Characteristic's (ROC) Area Under the Curve (AUC) analysis, we found that DPs and controls significantly differed in RT-ROCs for targets (AUC DPs=0.547, AUC controls=0.629, p<.01) but not for lures (p=.99). Further, the target AUC significantly predicted Cambridge Face Memory Test accuracy (CFMT, R=0.53) as well as DP diagnosis (AIC=68.0). Importantly, RT-ROC predicted unique variance beyond the recollection parameter derived from the dual process analysis of confidence ratings. Combined, they predicted 76% of the variance in DP diagnosis and 53% of the variance in CFMT. This suggests that RT-ROC is a useful, objective method of assessing face recognition abilities that provides different information than confidence judgments.

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The inseparability of visual processes in developmental dyslexia and the inseparability of visual categories in developmental prosopagnosia

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The selectivity of developmental prosopagnosia and dyslexia for stimulus category (faces or words), or process (featural or configural processing), is a subject of controversy. By manipulating featural and configural information in faces and houses, we investigated whether people with developmental prosopagnosia or dyslexia are disadvantaged in recognizing certain object classes or utilizing particular visual processing mechanisms. 34 dyslexic readers and 34 matched typical readers were tested in a delayed matching paradigm, and 28 individuals with prosopagnosia and 28 matched controls on a simultaneous matching task. Both tasks used the same stimuli. We used Representational Similarity Analysis (RSA) to correlate individual responses within each group and evaluate the similarity of these correlation matrices (reference models) with predicted data patterns (conceptual models). The reference models are correlation matrices of the accuracy of featural and configural processing of faces and houses with various difficulty levels. We created three conceptual models based on possible predicted patterns for categories, processes, and task difficulty level. If two different processes (featural or configural) or categories (faces or houses) are supported by separable mechanisms, we would expect performance for one type of process or category to better predict a trial involving an equivalent process or category than a trial involving a different process or category. RSA on behavioral data from the control groups revealed that featural and configural processes were clearly separable as were responses to stimulus category. In comparison, dyslexic readers appeared to rely on a single visual process regardless of whether features or configurations were task-relevant, and the prosopagnosia group did not perform differently based on stimulus category. We speculate that some dyslexic readers' reading deficits reflect their dependence on a single process for object recognition. In contrast, the inseparability of visual categories in individuals with prosopagnosia suggests that their recognition problem is not category selective.

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Typical visual processing of Navon-style compound letters and compound arrows in developmental prosopagnosia

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Developmental prosopagnosia (DP) is characterised by lifelong face recognition difficulties in the absence of brain damage. The study of DP has seen two longstanding debates: Are the observed deficits in DP face-specific or do they also impair the perception of non-face stimuli? Is DP associated with reduced ability to form integrated global representations (aberrant ‘configural’ processing)? Findings from the Navon paradigm are potentially important because they inform both debates. In this task, participants make decisions about the local elements and global configuration of compound stimuli. Arrangements can be consistent whereby the local elements match the global configuration (e.g., multiple small S’s arranged to form a large S) or inconsistent whereby there is a mismatch between the local elements and the global configuration (e.g., multiple small S’s arranged to form a large H). Participants are slower to identify the local elements and global configuration of inconsistent arrangements, suggestive of global-to-local and local-to-global interference, respectively. There has been much speculation that DPs perform atypically on this paradigm, potentially suggestive of aberrant global shape processing. However, existing studies with relatively small samples of DPs have yielded mixed results. Here, we aimed to test a larger sample of DPs on two versions of the Navon paradigm. In one task, compound stimuli were constructed from letters. In a second task, compound stimuli were constructed from arrows. Our preliminary results suggest that DPs (N = 14) and age-matched controls (N = 120) show comparable performance on these tasks. Both groups exhibit clear local-to-global and global-to-local interference effects. Both groups also show clear global precedence effects whereby participants identify the global configuration more quickly than the local elements. All effects were seen independently with compound letters and compound arrows. These results suggest that the perceptual deficit seen in DP does not disrupt performance on the Navon task.

Do developmental prosopagnosics with high vs. low levels of autism traits differ in how they process faces?

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Developmental prosopagnosia (DP) studies have routinely excluded individuals with high autism traits, assuming that DPs with high levels of autism traits have qualitatively different mechanisms of face recognition impairment, e.g., caused by social motivational factors. Indeed, autism spectrum disorders (ASD) are associated with face recognition memory and face emotion processing deficits but largely unimpaired face perception and holistic face processing abilities, whereas DPs without ASD have shown face perception and holistic processing deficits in addition to face memory deficits. To investigate the relationship between autism traits and face processing in DP, we administered a large behavioral battery and a face/scene/object/body fMRI localizer to 43 DPs with a wide range of Autism Quotient (AQ) scores as well as 27 healthy controls. When comparing the high (n=15; met broader autism phenotype classification) and low (n=28) AQ DP groups (AQ: 28.33 vs. 14.50; p<.001), we found a similar pattern across face processing tasks, with no differences in face matching (Cambridge Face Perception Test; p=.617), holistic face processing (Inversion effect: p=.644; Part-whole effect: p=.170), featural processing (Eyes: p=.643; Mouth: p=.984), or face memory (Cambridge Face Memory Test; p=.598). Both DP groups performed significantly worse on the face processing tasks compared to the control group (p’s<.05), with the exception of the mouth composite. As expected, the higher AQ group showed significantly decreased face emotion recognition compared to the low AQ group (p=.028). During the fMRI localizer task, both DP groups showed similarly reduced face selectivity in the left occipital and fusiform face areas compared to controls. Notably, the higher AQ DPs also showed decreased face selectivity in the bilateral posterior superior temporal sulcus compared to the lower AQ DPs. These results suggest that high autism traits do not result in qualitatively different face processing in DPs, but are associated with greater face emotion recognition impairments.

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No association between face identification abilities and “mind-reading” in the eyes

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Recently, we showed that face identification ability is related to a systematic increase in the use of the eye area (Royer et al., 2018). One hypothesis that may explain these results is that individuals with higher ability better process the fine and complex perceptual information within the eye area and this, irrespective of the task. To investigate this, we asked 71 participants to perform both the Cambridge Face Memory Test (CFMT; Duchaine & Nakayama, 2006) and the Reading the Mind in the Eyes Test (RMET; Baron-Cohen et al., 2001). The CFMT measured face identification and face memory abilities, and the RMET measured the ability to infer mental states from subtle facial expressions in the eye region. No correlation was found between the two tests ($r=-0.02$, $p=0.89$). Since the RMET is an easy task and following the idea that individual differences in face processing could be explained by a better ability to extract subtle visual cues in the eye region, we divided the RMET in two according to the level of difficulty of each item (see Domes et al. 2007). Again, no correlation was found between the CFMT and the scores on the difficult items of the RMET ($r=0.06$, $p=0.62$). Many explanations are possible for this negative finding. It is indeed possible that face processing abilities are task specific i.e., do not generalize to other face-processing tasks such as the RMET. Another intriguing possibility is that the better utilization of the eyes in face identification comes from an attentional bias for this part of the face. Since only the eye area is visible in the RMET it is possible that this eliminates the difference between the individual with lower and higher abilities. More research will be needed to better understand the mechanisms associated with individual differences in face recognition.

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Poster Session A > Face Perception: Individual differences 1 > Poster A131

Persisting Prosopagnosia due to COVID-19

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COVID-19 causes neurological problems including the loss of smell and taste (Mao et al., 2020), long-lasting memory, speech, and language impairments (Davis et al., 2020), and psychosis (Varatharaj et al, 2020). Visual problems have also been reported but no detailed case studies of the effects of COVID-19 on visual functions have been reported (Mao et al., 2020). Here, we provide the first report of a case of prosopagnosia following COVID-19. Annie is a 26-year-old woman who contracted COVID-19 in March 2020. She first noticed face recognition difficulties in June 2020 which have persisted for more than six months. Annie's difficulties affect the recognition of faces that she is extremely familiar with. For example, when talking to her father she had the feeling that "My father's voice came out of a stranger's face." On four tests of facial identity recognition (CFMT, Famous Faces, Old-New, Doppelganger), Annie showed clear impairments. She also scored more than one standard deviation below mean on the Cambridge Face Perception Test. In contrast, Annie scored normally on visual recognition tests involving objects and scenes, and on non-visual memory tests. Navigational deficits are common in acquired prosopagnosia (Schmidt, 2015), and Annie has noticed that her navigational abilities are substantially worse than they were before she became ill. She reports that she now has to think about where the dairy section is in her grocery store, she gets lost frequently, and has trouble finding her car in parking lots. Annie is the first documented case exhibiting selective impairments to face processing and navigation as a consequence of COVID-19. Whether a COVID-19 induced stroke caused Annie's impairments is currently being assessed through MRI scans. Survey data we collected from 83 additional COVID-19 survivors indicates that navigational, object, and scene processing difficulties are not uncommon in COVID-19 survivors even after recovery.

Poster Session A > Face Perception: Individual differences 1 > Poster A132

Modelling individual preferences reveals that face beauty is not universally perceived across cultures

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Face attractiveness confers considerable advantages in social interactions, with preferences likely reflecting psychobiological mechanisms shaped by natural selection. Theories of universal beauty propose that attractive faces comprise features that are closer to the population average while optimizing sexual dimorphism (masculine vs. feminine distinction). However, emerging evidence questions this model as an accurate representation of attractive faces, including representing the diversity of beauty preferences across cultures and their individual members. In this study, we used a data-driven method to model, at the individual and cultural levels, the features of attractive female faces, in two matched groups of young male participants (40 East Asians and 40 Western Europeans). We first generated a broad range of same- and other-ethnicity female faces with naturally varying shapes and complexions that participants rated on attractiveness. Then, we reverse correlated the specific features that modulated the perception of face attractiveness in each individual participant. From these individual models, we reconstructed the representation space of face attractiveness. In contrast to theories of universal beauty, we show that attractive face features are distinct from the average (and from sexual dimorphism) in both cultures. We then disentangle attractive face features into those that are shared across cultures, those that are culture-specific, and those that are specific to the individual participant. Our demonstration reveals that face beauty is grounded in diverse features sensitive to culture and ethnicity. Our results have a direct theoretical and methodological impact for representing diversity in theories of social perception and application for the design of culturally and ethnicity sensitive digital agents.

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Perception and Action: Decision making, models, neural mechanisms

Poster Session A > Perception and Action: Decision making, models, neural mechanisms > Poster A133

Go-/ no-go decisions based on gradually revealed visual information.

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In everyday life, we often need to choose whether to move or not to move based on rapidly evolving, and potentially incomplete information. Here, we investigated how visually presented, gradually updated information influences a manual response. We used a go-/ no-go task in which we prompted observers to decide if a horizontally moving stimulus (attacker) would hit or miss a hidden goal. The vertical location of the goal was revealed gradually, by showing a sequence of six dots over the course of 1 second, providing independent samples of positions inside the goal. Observers had to touch the monitor at the goal (‘go’ response) within 1 second after the attacker started to move, but only if they thought that the attacker would intercept the goal (‘in’ trial). As a measure of uncertainty, we computed the probability of an ‘in’ trial (p'in') after each new sample. Higher probabilities of an ‘in’ trials were associated with more ‘go’ responses, and lower probabilities were associated with more ‘no-go’ responses. This pattern was also explained by the vertical distance between the samples and the position of the attacker. Comparing p'in' in correct and incorrect trials, we found that information carried by the first two samples (presented 0 and 166 ms after trial onset), differed between correct and incorrect responses. Incorrect ‘go’ responses were characterized by higher p'in' values in these time windows, and incorrect ‘no-go’ responses by lower p'in' values, compared to the correct responses in each response category. Overall, our results suggest that human observers exploit gradual updates of information for a go/no-go decision. When later samples provided evidence contradictory to former ones, responses were better explained by the later samples, indicating that an imminent decision is rapidly modified to take into account newly available information.

Acknowledgements: Berlin School of Mind and Brain

Poster Session A > Perception and Action: Decision making, models, neural mechanisms > Poster A134

Motor inhibition processes in Go/No-Go and Stop Signal Tasks: New insight from

mouse tracking

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Action control can be guided by visual stimuli, particularly in situations with stringent time/accuracy constraints as in certain sports. Action implementation and inhibition in response to visual targets have been studied in relation to proactive and reactive cognitive control. In those studies, performance is typically recorded by keypress methods that could be insufficient to capture dynamic response features. We used a mouse-tracking procedure to evaluate movement velocity profiles related to proactive and reactive control during two inhibitory visuomotor tasks. Participants performed a cued Go/No-Go (cGNG), with high&low Go-stimulus occurrence conditions, which mainly involve proactive control; and a Stop Signal Task (SST), where the reactive component is engaged. We hypothesized that different movement profiles could be associated with inhibitory failures between tasks, reflecting the influence of proactive/reactive mechanisms on motor preparation and execution. Set-up consisted of a mouse-device positioned in the centre of a board. For Go-conditions, subjects were instructed to move the mouse quickly and accurately in the direction indicated by the Go-stimulus (i.e., left/right) until reached a set barrier. For No-Go/Stop conditions they were requested not to move the mouse. Movements with a smooth profile without corrections were classified as 'one-shot'. Multi-peaked profiles, reflecting movement alterations, were classified as 'non-one-shot'. A significantly higher proportion of one-shots was found in the SST (81±9%) compared to the cGNG (high:21±34%, low:30±33%) for inhibition failures ($p<0.001$). No difference emerged between tasks for Go-conditions. Profiles revealed that inhibitory failures are differently modulated under mainly reactive/proactive control: corrections to the initial motor plan were less frequent under mainly reactive control, suggesting that the influence of inhibitory control mechanisms on motor planning may be marginal. The opposite trend emerged for mainly proactive control. Additionally to these findings, a preliminary comparison between professional athletes and non-athletes is reported to address whether and how experience plays a role.

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Differential effects of positive and negative reward prediction error on saccade response time adaptation in a reversal learning visual stop-signal task

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Intelligent agents adapt behavior based on updated knowledge of reinforcements in visual tasks. However, not all experiences are equally important in driving adaptive behavior and the mechanism by which different information influence our behavior depends on their nature. We trained four macaque monkeys (1 female) to perform a visual stop-signal task in which fluid reward was earned for shifting gaze to a visual stimulus (either left or right), unless a visual stop-signal instructed the monkey to cancel the movement. Stop-signal delay was adjusted to ensure successful stopping on ~50% of stop-signal trials. New here, reward amount was asymmetric for the two directions with block-wise alternation across positions. As expected, response time (RT) was faster for high-reward compared to low-reward locations. With each block reversal, RT to the high-reward location (associated with low reward in previous block) decreased and RT to the low-reward location (associated with high reward in previous block) increased until they plateaued over several trials. Because of the binary nature of reward association, a rational observer could gain knowledge about block switch equally from low reward (negative reward prediction error (RPE)) and high reward (positive RPE) trials. Using mixed-effects modeling of RT, we tested whether macaque monkeys' performance conformed to the rational observer hypothesis. Specifically, we examined the contribution of negative and positive RPE trials to the rate of RT-speeding and RT-slowing. Compared to negative RPE trials, positive RPE influenced RT-speeding significantly more in three of four monkeys. However, the relative effect of positive and negative RPE on RT-slowing was more idiosyncratic across monkeys. These results provide evidence against the rational observer hypothesis, indicate that RT-speeding and RT-slowing are mediated by different mechanisms, and reveal subject-specific factors necessary for interpreting neural signals related to reinforcement learning of visual tasks.

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Poster Session A > Perception and Action: Decision making, models, neural mechanisms > Poster A136

Decision-Making in Human Crowds: Nonlinear Competition Dynamics

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When a crowd splits into two groups walking in different directions, how does an individual decide which group to follow? We previously found (VSS 2019) that participants average the heading directions of all neighbors in the field of view up to an angular difference of 40° between groups, consistent with Rio, Dachner & Warren's (PRSB 2018) neighborhood model. Here we investigate what rules govern individual decisions with larger angular differences (≥80°).Participants (N=10) were instructed to "walk with" a virtual crowd (8 or 16 virtual humans) while wearing a Samsung Odyssey HMD (110º FOV). After 2-3s, one group made a small turn (20° left or right) and the other group made a large turn (60°, 100°, 140°, or 180°) in the other direction. We manipulated the percentage of the crowd making the large turn (0%, 25%, 50%, 75%, 100%), and measured the participant's walking direction. The results show a strong attraction to follow the majority ($p<0.001$), with no influence of total crowd size ($p=0.27$, contrary to a quorum). However, this effect trades off with an attraction to the smaller (20°) turn: as the magnitude of the large turn increased, participants were more likely to follow a minority making the smaller, less effortful turn ($p<0.001$). Interestingly, there were individual differences: while most participants followed this trade-off, a few always preferred either the majority or the small turn. To model this data, we introduced nonlinear competition dynamics into our neighborhood model, such that an individual decision is driven by the relative weight of the crowd proportion and the angular difference between groups. We fit the competition parameters to each participant, and simulated heading in all experimental trials. The new model accounted for 86% of the individual decisions in the data set.

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Near-instantaneous choices in a tapping task

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Throughout their daily life people constantly make minor choices such as where to direct their gaze or where to place their foot. Classic reaction-time studies have shown that it takes longer to respond when one must choose between more options. However, in such studies the correct choice was defined by the experimenter and was arbitrarily related to a particular stimulus attribute. In contrast, in daily life there are often many viable options while the relationship between the stimulus and the most adequate response is not arbitrary. We therefore examined how much time it takes to make choices in such a situation. We also evaluated whether the participants' choices were adequate. The task was to collect points by tapping on as many targets as possible within a limited amount of time. After each tap a new set of targets appeared. We found that it took about 150 ms to choose a target, with only a modest influence of the number of options and the relevant stimulus attribute. Moreover, participants usually made reasonable choices considering the circumstances. They chose larger and more advantageously positioned or oriented targets when doing so allowed them to reach the targets faster, but when the target's colour indicated that it was worth more points they chose it less often than they should have. Altogether, people appear to make near-instantaneous choices between multiple alternatives based on task-relevant features when they are free to choose rather than being instructed as to what to choose.

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Effects of visually masked numbers and lines on brain activity

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A frequently used paradigm to investigate unconscious processing of visual stimuli is masked priming. Traditionally, a direct task is compared to an indirect task: In the direct task, detection of a masked prime stimulus is typically found to be close to chance-level. In the indirect task, effects of the prime on reaction times to a subsequent target stimulus are analyzed (priming effects). Here, we focus on the indirect task and use event-related potentials (ERPs) to examine the effects of the masked primes on brain activity. Previous studies found that early deflections in the lateralized readiness potential (LRP), a measure of specific motor activation, reflect correct and incorrect response activations by the prime. This supports the idea of prime-induced covert motor activations that conflict with the responses required by the target. To test this, we performed two experiments using masked priming with numbers (Exp. 1) and simple line stimuli (Exp. 2). Additionally, in Exp. 1 prime contrast was varied to modulate visibility of the numbers. Preliminary results show that ERP onset latencies for congruent vs. incongruent trials measured at electrode Cz (Exp. 1: normal contrast: M=12 ms, $p<.001$ / high contrast: M=21 ms, $p<.001$; Exp. 2: M=51 ms, $p<.001$) closely matched the behavioral priming effects (Exp. 1: normal contrast: M=9 ms, $p<.001$ / high contrast: M=21 ms, $p=.003$; Exp. 2: M=46 ms, $p=.001$). In addition, we found more negative deflections in the early LRP phase for incongruent as compared to congruent trials in Exp. 2 (albeit not in Exp. 1). Overall, the results support the idea of prime-induced pre-activated motor responses. We discuss differences between the experiments and to which extend the behavioral results are related to the ERP effects.

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Modeling associative motor learning through capacity-limited reinforcement learning

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Perception fundamentally supports the achievement of behavioral objectives, however human perceptual processing, like any physical information channel, is capacity-limited. These processing limits influence decision outcomes at multiple levels, as the response selection necessary for intelligent behavior is also constrained at motor, perceptual, and cognitive levels. When task demands are high, such as when the appropriate action(s) are associated with multiple visual cues, perceptual and cognitive constraints (e.g. working memory) are especially important parameters for performance. In such circumstances, the individual must balance a trade-off between the computational goals of achieving good performance and minimizing the complexity of the behavioral policy — the mapping between perceptual cues and actions. In the present work we examine how people balance these trade-offs in a motor learning paradigm. The experiment required participants to learn a mapping between visual cues and simple motor responses where pushing a target with the appropriate amount of contact force earned points. In addition, the task was designed to manipulate information processing demands by varying the number of stimulus-action pairings (set-size). In general, performance increased monotonically with policy complexity, and was lower in larger set size conditions. We utilize the formal mathematics of rate-distortion theory, a branch of information theory (Shannon, 1948) to develop a model of optimal task performance subject to information processing constraints that compliments the empirical results. Secondly, we also extend the rate-distortion objective to the reinforcement learning (RL) framework. This approach treats the agent’s behavioral policy as a capacity-limited information channel that is unable to represent cue-action mappings with perfect fidelity. When compared to standard RL models, the capacity-limited RL model was able to capture the qualitative differences between conditions. Together this work highlights the importance of methods that consider resource constraints in modeling performance.

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The Black Hole Illusion: Theory and Tests

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The Black Hole Illusion (BHI) is a nighttime aviation landing illusion that occurs when only the runway is visible to pilots. With this illusion, pilots overestimate their descent angle, which causes them to overestimate their height, compensate by flying lower, and crash into the ground. Perrone (1983) proved that, in daylight conditions, it is possible to compute the descent angle using a ratio of retinal distances of the runway. He also showed that using a modified algorithm, which applies in nighttime conditions with just the visible runway, pilots would overestimate the descent angle, ultimately leading to the BHI. We quantitatively analyzed Perrone's algorithm to determine whether it is a viable explanation for the BHI. Our analysis finds that, if Perrone's algorithm was a complete explanation of the BHI, pilots would sometimes crash planes nearly half a kilometer before the start of the runway, which is much larger than what has been observed. To further investigate the role of Perrone's algorithm, we derived and tested two additional predictions. First, we quantified an observation made by Perrone that the BHI illusion magnitude should be affected by the runway width. Second, we discovered that some conditions of runway width and length predict a reverse BHI such that pilots should underestimate their angle of descent and compensate by flying higher (and landing later) than is necessary. We are empirically testing our predictions with an on-line experiment using simulated landing flight paths. Participants observe a cockpit view of a runway during five seconds of approach. In a subsequent still image, the participant indicates where they believe the plane will land if it continues on its flight path. We measure the accuracy of landing positions for various runway widths/lengths and for various background contexts: Black, green, and textured grass.

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Mixed selectivity in macaque medial parietal cortex for gaze and motor parameters

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The posterior parietal area V6A in monkey is a key node of the dorso-medial visual stream. V6A is heavily involved in sensory-motor transformations and is modulated by a plethora of different factors during visually guided reaching tasks. Most past works studied the encoding of gaze position/saccades or reaching movement separately. Although traditionally this simplification makes data more interpretable, it fails in providing an overall picture of V6A multimodal representations. Thanks to the flexibility offered by Generalized Linear Models (GLMs), these separate approaches can be combined in a unique framework, thus making it possible to study how a variety of information is encoded in individual cells. In the present study, we recorded 181 neurons from V6A in two Macaca fascicularis monkeys while the animals performed in darkness a delayed reaching task towards 9 visual targets placed at different directions and depths. We then built, for each cell separately, a Poisson GLM that included variables related to gaze and arm movements. The fitted models were able to explain neural activity before the task, when eye movements were still allowed, as well as during the reaching, when gaze was blocked on the visual target. We finally computed a 'functional fingerprint' representative of each neuron modulation. We found that variables related to gaze position as well as arm movement were randomly distributed and mixed in V6A neural population, rather than being segregated in different subpopulations of cells. Compared to previous works, our results provide for the first time a detailed quantitative account of how multiple, heterogeneous parameters, linked to both visual and motor domain, are encoded in V6A at single cell level and in a single task, offering an important contribution in understanding the integration of different inputs within the posterior parietal cortex.

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Poster Session A > Perception and Action: Decision making, models, neural mechanisms > Poster A142

Precise functional connections from the dorsal anterior cingulate cortex to the intuitive physics network in the human brain

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Recent work has identified a set of brain regions that are recruited when people predict how the physical behavior of the world will unfold (here termed the intuitive physics network; IPN). Mounting evidence supports the characterization of

this network as a physics simulation engine in the brain, but many fundamental questions about the architecture of the IPN remain unanswered. One such question is what regions provide the key inputs to the network, supplying the necessary information for physical prediction and regulating when and how the IPN is engaged in service of our goals. Here, we investigated the dorsal anterior cingulate cortex (dACC) as a candidate for regulating IPN function. The dACC has long been implicated in "attention for action", driving the focus of processing toward specific object features that are crucial for planning behaviors. The dACC is also richly interconnected with the general regions of frontoparietal cortex where the IPN is situated, but no study has yet investigated whether these connections specifically target the IPN. To address this question, we collected resting state fMRI recordings in seventeen individuals and independently localized the IPN in each person. We computed the resting state correlations of the dACC with voxels across the rest of the brain and found that the strongest functional connections of the dACC not only aligned well with the IPN at the group level, but also precisely mirrored individual differences in the positioning of IPN regions across participants. This tight correspondence points to the dACC being an important input to the IPN. Taken together with previous findings, our results suggest that the dACC might be a key structure for regulating the engagement of the mental physics engine based on motivation, and may provide an interface between the IPN and the brain systems for other cognitive domains such as social reasoning.

Perception and Action: Action and body perception 1

Poster Session A > Perception and Action: Action and body perception 1 > Poster A143

Decoding observed actions at the subordinate, basic and superordinate level

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Similar to objects, actions can be described at different hierarchical levels, ranging from very broad (e.g., locomotion) to very specific (e.g., breaststroke) information. Here we aimed to determine distinct representations of observed actions at three different levels of abstraction (superordinate, basic, and subordinate) in the human brain. To address this question, we conducted an fMRI study (3T; voxel resolution 2.5*2.5*2.5, TR= 2s, multiband sequence, acceleration factor 3) in which we presented N = 23 participants with static images of twelve different actions (six exemplars each) that were divided into three superordinate, six basic and twelve subordinate action categories. Participants were instructed to view the images, and to perform a category verification task during occasional catch trials, with an equal proportion of questions for each of the three taxonomic levels. Multivariate pattern analysis was carried out on t-values resulting from a general-linear model analysis, using a linear discriminate analysis (LDA) classifier and independent exemplar cross validation. To be able to compare results between the three taxonomic levels, decoding accuracy was normalized to account for the differences in chance level. A ROI-based analysis revealed that normalized decoding accuracy for the distinction between observed actions was higher at the subordinate in comparison to the superordinate level in V1, right superior parietal lobule (SPL) and right premotor cortex. By contrast, decoding accuracy in the right lateral occipitotemporal cortex (LOTC) and the left SPL was higher at the basic level than the superordinate level. Furthermore, the whole-brain searchlight analysis revealed peaks in the right inferior lateral occipital cortex (LOC), the left temporal occipital fusiform cortex and the right superior LOC for the subordinate, basic and superordinate level, respectively. Together, our results are in line with the view that observed actions can be decoded at all three taxonomic levels in high-level visual cortex.

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Poster Session A > Perception and Action: Action and body perception 1 > Poster A144

Emotional body language mediates activity in the macaque body patches

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Facial expressions are powerful signals that communicate information about our emotional states to other people. Additionally, behavioral evidence suggests that body language also conveys emotional signals, yet we do not fully understand how the brain responds to body expressions. In the macaque brain there is a discrete network of patches in inferior temporal (IT) cortex that are selectively activated by bodies (Premereur, et al., 2016, Curr Biol. 26(24): 3269-79). Our aim in this study was to determine whether these cortical body-selective patches respond more to fearful bodies in comparison to neutral bodies. We used whole-brain functional imaging to first localize the body-selective patches in two subjects (Macaca mulatta). Then, while the same subjects were awake in the scanner, we presented them with images of bodies that were classified as either fearful or neutral. We also manipulated the orientation of the stimuli (upright vs. inverted) and the species of the stimuli (macaque bodies vs. human bodies). In both subjects we found that the body-selective patches were more activated by fearful bodies than neutral bodies, regardless of species. Further, while stimulus orientation modulated the response to fearful human bodies, it did not affect the response to fearful macaque bodies. These results distinguish the body-selective patches from the adjacent face-selective patches, where activity was influenced more by orientation and less by emotional valence. The observed differences between these two category-selective networks shed light on the functional architecture of IT cortex and its relationship with the amygdala.

Acknowledgements: Laboratory of Brain and Cognition, NIMH

Poster Session A > Perception and Action: Action and body perception 1 > Poster A145

Revealing the architecture underlying the representation of observed actions - evidence from behavioral and fMRI studies

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Every day, we encounter people performing various different types of actions, which we are able to understand quickly and effortlessly. Despite this seemingly trivial task, our knowledge regarding the way in which the human brain represents observed actions and assigns meaning to them is still limited. In order to address these questions, we examined the cognitive and neural organization of 100 actions depicted as static images, taking inspiration from the rich literature on object representations. First, to examine the (1) category- and (2) feature-based organization, we performed several behavioral studies using inverse multidimensional scaling analysis and feature ratings. To compare the two resulting category- and feature-based model against a semantic model, we constructed a third model using word embeddings (Bidirectional Encoder Representations from Transformers; BERT). Next, we conducted an fMRI study and performed a representational similarity analysis (RSA) using the three models. A ROI-based RSA in occipito-temporal, parietal and frontal nodes of the action observation network revealed a significant correlation between the neural data and the feature-based model in the left lateral occipitotemporal cortex (LOTC) and the left inferior parietal lobule. The category model significantly correlated with neural data in the right LOTC. The semantic model significantly correlated with neural data in the left and right LOTC. An additional whole-brain GLM-based searchlight RSA revealed the peak for the feature model in the left lingual gyrus, for the category model in the right middle temporal gyrus (MTG), and for the semantic model in the right LOTC. Overall, our results highlight the importance of occipito-temporal regions for the processing of information related to features, categories and semantics and suggest a division of labor between the left and right LOTC.

Acknowledgements: The project was supported by the German Research Foundation

Poster Session A > Perception and Action: Action and body perception 1 > Poster A146

Perceiving social events in a physical world

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How can we tell that a falling leaf is an object? That a ball hitting a basket was likely launched by an intelligent mind? The spontaneity of social perception hides a rich complexity of inferred agency: agents' intentions and plans; states of mind, and relationships; reasoning about physical forces and constraints (Heider and Simmel 1944). Many studies examined aspects of perceived agency, and proposed models of joint belief-desire inference. However, most are limited to simple displays. Here, we introduce a system for generating Heider-Simmel-like animations of social interactions in a physical world. The animations can be synthesized automatically, using a hierarchical planner and a physics engine, and via an online interface, where humans control geometric shapes to enact social interactions. The resulting animations depict agents and objects in a continuous physical world, with landmarks and obstacles. Agents have a limited field of view, and can interact in ways such as helping, fighting, chasing, cooperating, carrying, etc. Our system enables a procedural generation of hundreds of unique animations, which can be used for human studies, or for benchmarking machine perception. The system provides a record of trajectories of all entities, forces exerted by agents, as well as agents' goals, relationships, and strengths. Experimental evaluation shows that humans describe the depicted scenarios as a wide range of real-life social interactions, rate the simulated agent behaviors as highly human-like, and infer the agents' goals and relationships accurately. While human inferences of the agents' goals and relationships are predicted with a high accuracy by a Bayeisan inverse planning-based method, state-of-the-art DNN models fail to achieve similar results. In addition, we are also able to train a DNN to detect animacy using synthesized stimuli and probe what visual cues about animacy it can learn and whether they would match with well-known cues used by humans.

Acknowledgements: This work was supported by NSF STC award CCF-1231216 (the Center for Brains, Minds and Machines), ONR MURI N00014-13-1-0333, the MIT-Air Force AI Accelerator, Toyota Research Institute, the DARPA GAILA program, and the ONR Science of Artificial Intelligence program.

Poster Session A > Perception and Action: Action and body perception 1 > Poster A147

Seeing others’ intentions in autism

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Background: The ability to infer the intentions of others by observing their movements is crucial for social interactions. Children with autism spectrum disorders (ASD) are delayed in the development of this ability, with knock-on consequences across lifespan. Here we report on a study combining motion tracking, psychophysics and computational analyses to compare intention readout in typically developing (TD) children and children with ASD. Methods: Eight- to thirteen-year-old TD children (n=37) and ASD children without accompanying intellectual impairment (n=35) watched a hand reaching for a bottle, either to pour or to place, and judged on the intention of the observed grasp. In a within-subjects counterbalanced order, participants watched videos of actions performed by TD children and ASD children. Using a time-dependent logistic regression fitted to the experimental data, we analyzed how intention encoding – the mapping of intention to movement kinematics during action execution – and intention readout – the mapping of visual kinematics to intention during action observation – intersect at a single-trial level in TD children and children with ASD. Results: Whilst intention readout was sensitive to variations in visual kinematics in both groups, the proportion of individuals with intention readout sensitive to visual kinematics (‘readers’) was lower in the ASD group than in the TD group ($p<.01$). A significant proportion of TD readers was able to infer the correct intention, when observing both TD and ASD actions (ASD actions: $p<.01$; TD actions: $p<.001$). ASD readers failed to map visual kinematics to the correct intention regardless of whether they observed TD or ASD actions. Conclusions: Whilst observers with ASD are not blind to subtle variations in visual kinematics, they are unable to link such variations to the correct intention. These findings have implications for understanding how misalignment between intention encoding and readout impact social interactions in autism.

Face Perception: Individual differences 1

Poster Session A > Face Perception: Individual differences 1 > Poster A148

Individual differences in classification images of Mooney faces

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In a previous study, we found that there are stimulus-specific individual differences in holistic processing of Mooney

faces (two-tone, shadowy images of faces; Canas-Bajo & Whitney, Frontiers in Psychology, 2020): specific faces that are processed holistically by one observer are not necessarily processed holistically by other observers. However, the origin of those individual differences remains unclear. One hypothesis is that each observer has a unique family of face templates—a template manifold—which is formed over a lifetime of experience. Faces that are similar to an observer's particular face templates would have an advantage over faces that differ more from the observer's templates. In the present study, our goal was to test whether such individual differences in face templates exist. To test this hypothesis, we used a reverse correlation approach to measure individual differences in classification images for Mooney faces. On each trial, a pair of identical Mooney face images were embedded in random but complementary noise and participants judged which image was more face-like (2AFC). Classification images were visualized by averaging the chosen noise images, and null distributions were generated from shuffled responses. We found that classification images were consistent within each observer but were different between observers. Our findings suggest that humans have consistent and unique face templates that could drive idiosyncratic individual differences in face recognition.

Poster Session B

Spatial Vision: Crowding

Poster Session B > Spatial Vision: Crowding > Poster B1

The role of crowding in mental maze solving

View Poster | Visit me in Gather.Town Osprey Room on Sunday 8:00 am - 10:00 am EDT

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Studying peripheral vision requires sufficiently complex stimuli and well-defined tasks. Here for this purpose, we explore the use of mental maze solving -- tracing a path through a maze without a pen or a finger. Mental maze solving involves both cognitive and perceptual processes and can provide a controlled environment to study visual crowding, a well-known limiting factor in peripheral vision. The task requires observers to make a series of eye-movements and combine multiple views of the maze into a stable representation, which could then enable observers to decide where to look next. In the current study, we investigated visual crowding by measuring maze solving performance as a function of maze appearance, recording eye-movements, and modeling the results. Human observers solved a series of 2D mazes while we recorded the time to solve each maze and eye-movements. The perceptual features of mazes were manipulated to alter the level of crowding in each maze (i.e., path thickness, visual complexity). Experiments 1&2 showed that observers were faster at solving mazes with thinner and less-complex paths, suggesting visual crowding is a significant factor in determining maze solving performance. In Experiment 3, we tested whether a crowding model (The Texture Tiling Model; TTM) can predict fixation allocation during maze solving. Observers were slower and made a larger number of eye-movements while solving crowded mazes, as predicted by TTM, although TTM underpredicts the number of fixations. To examine this underestimation tendency, in Experiment 4, we tested whether observers could detect targets placed on/off the maze paths near the model fixation locations. Preliminary data suggest that observers were over 70% accurate in detecting targets, even though targets were located on average 2.7 times farther than their fixation locations. These findings suggest visual crowding as a significant factor in mental maze solving.

Poster Session B > Spatial Vision: Crowding > Poster B2

More crowded, less numerous: Crowding reduces the number of perceived items in numerosity perception

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Sunday 8:00 am - 10:00 am EDT

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Crowding refers to the deleterious effect of flankers on target perception. Recently, it has been proposed that crowding may have an impact on non-symbolic number processing. To investigate the role of crowding in numerosity perception, we used the radial-tangential anisotropy of crowding: radially placed flankers interfere more strongly with target perception than tangentially placed flankers. Stimuli consisted of different numbers of black discs presented on a gray background. We generated displays with different crowding levels (‘crowding’ and ‘no-crowding’ displays) while keeping other physical properties of the displays (e.g., inter-item spacing, occupancy area, convex hull, and density) as similar as possible. Displays consisted of a group of ‘base’ and ‘extra’ discs. ‘Crowding’ displays were generated by adding an extra disc inside the radially elongated elliptical crowding region of the base disc. ‘No-crowding’ displays were generated by rotating the elliptical crowding region (90 degrees) and adding an extra disc inside the (now tangentially elongated) ellipse around the base disc. In each trial, a reference display and a probe display appeared sequentially on the screen. Each ‘crowding’ and ‘no-crowding’ reference display was paired with ‘crowding’ as well as ‘no-crowding’ probe displays. The reference displays contained 40 discs, and probe displays contained 34, 36, 38, 40, 42, 44, or 46 discs. Participants were required to indicate the display that appeared to be more numerous. We found that subjective equality between crowding and no-crowding displays was shifted towards smaller numerosities in no-crowding displays, indicating that crowding displays were perceived as less numerous than no-crowding displays. The relative underestimation in the ‘crowding’ compared to the ‘no-crowding’ condition showed that radial compared to tangential arrangements reduced the

number of perceived discs. Our results suggest that numerosity perception is subject to a radial-tangential asymmetry that may be driven by crowding.

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Poster Session B > Spatial Vision: Crowding > Poster B3

The role of transient attention on the inner-outer asymmetry of crowding

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Sunday 8:00 am - 10:00 am EDT

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Background: Crowding refers to the failure to identify a peripheral object because other objects (flankers) surround it. A hallmark characteristic of crowding is the inner-outer asymmetry, i.e., the unintuitive fact that the outer flanker produces more substantial interference than the inner one. Despite recent efforts to explain this characteristic of crowding, the processes that underlie the inner-outer asymmetry are still unclear. Here, we investigated the role of attention in visual crowding by investigating whether and how spatial transient attention interacts with its flankers' asymmetrical effect. Method. Eighteen observers estimated the orientation of a Gabor target presented at 7° eccentricity. The crowding display consisted of two flankers along the horizontal meridian, one on each side of the target. We manipulated attention by using a pre-cue that could appear at one of four possible locations: fixation, target, inner-flanker, or outer flanker. We assessed each flanker's contribution to the pattern of errors by fitting probabilistic mixture-models. Results. Consistent with our previous findings, observers often misreported the outer (eccentric) flanker as the target (reflecting the inner-outer asymmetry). Interestingly, directing transient attention to the inner flanker location reduced crowding interference by decreasing the outer flanker reports. However, directing attention to the outer flanker location increased the crowding interference by increasing the outer flanker reports. Conclusions. The present results are inconsistent with some of the current crowding models (e.g., the cortical magnification and the receptive size views). Our findings suggest that spatial attention plays an essential role in the inner-outer asymmetry, a hallmark characteristic of crowding.

Poster Session B > Spatial Vision: Crowding > Poster B4

Probability cuing uncovers object-based frames of reference in crowding

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In visual crowding, nearby objects (flankers) impair target perception. Focused spatial attention to the target location has been shown to reduce crowding. However, how attentional allocation within a group of close-by objects modulates crowding is largely unknown. Here, with probability as attentional cue, we varied the target location within a group of objects to investigate how object-based attention affected crowding. Observers reported either the inward, central, or outward letter of a letter trigram, as indicated by a pre-cue (Experiment 1) or a post-cue (Experiment 2). Probabilities of which letter position to report were 100, 80, 50, and 33 percent, with an equal number of trials for the remaining letter positions. Trigrams were briefly presented at varying eccentricities (centered at 8.6°, 10°, or 11.4°), while keeping the target location fixed throughout (at 10°). In both experiments, performance for the central letter was inferior compared to both flanking letters, and, consistent with the inward-outward anisotropy of crowding, worse for the inward compared to the outward letter. Probability affected none of the letter positions when pre-cued, but all letter positions improved with higher probabilities when post-cued. The post-cue results revealed that, despite all target letters being presented at the same spatial location, crowded letter recognition benefitted from increased attention towards a given letter position within the trigram. Hence, performance was strongly dependent on an object-based frame of reference when all letter positions within the trigram were task-relevant. We suggest that the allocation of attention within groups of task-relevant objects strongly affects the recognition of crowded items.

Acknowledgements: Swiss National Science Foundation (SNF grant PP00P1_163723)

Poster Session B > Spatial Vision: Crowding > Poster B5

Does the training on a visual crowding task alter the population receptive field estimates?

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Previous studies have shown that response properties of neurons can be changed as a result of disease or training. New advances in functional magnetic resonance imaging, specifically population receptive field (pRF) modelling method, can be used to estimate the changes in response properties of neurons induced by reorganization and/or optimization of local neural connections. In this study, we characterize the pRF model properties in healthy volunteers who were trained on visual crowding task at a specific retinal location over 3 consecutive days (totally 2022 trials). Pre- and post-training fMRI images were acquired in all participants using 3-Tesla MRI scanner (Prisma, Siemens). The pRF parameters were estimated by the BOLD signals during a moving bar presentation where an aperture (exposing a flickering checkerboard pattern) was drifting across the screen in 4 orientations and two drifting directions (i.e. 8 bar configurations). Participants were to perform a fixation task while passively viewing the moving bar. Two-dimensional spatial pRF profiles for each voxel were estimated by using SamSrf 7.07 toolbox. To define the region of interest (ROI) of the trained area in the visual cortex, a separate fMRI localizer scanning session was performed where the crowding stimuli used in the behavioral training sessions were presented. We found that after perceptual training, participants who achieved substantial improvement in crowding task (experiencing less crowding effect) exhibited decreased pRF size (defined by the sigma, the spatial spread of the pRF), while others who have not shown behavioral improvement demonstrated wider pRF inside the crowding ROI. These results demonstrate that perceptual learning can modify basic neuronal response properties at visual cortex and provide insights into the understanding of plasticity across adult visual cortex.

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Poster Session B > Spatial Vision: Crowding > Poster B6

Simplifying the repeated crowding-distance test for normal and amblyopic children.

View Poster | Visit me in Gather.Town Osprey Room on Sunday 8:00 am - 10:00 am EDT

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Crowding distance can be measured clinically with skinny Pelli optotypes that enable closer horizontal spacing. Crowding distance develops more steeply with age than visual acuity and is more pronounced in amblyopia. Adult amblyopes have unsteady fixation and spatially-repeated optotype tests minimize the effect of inaccurate eye positioning on measured crowding distance. However, young children are reluctant to engage in the full-screen repeated test due to its visual complexity, which could reduce participation rates. We sought to simplify the repeated crowding distance test to enhance engagement by young children, while retaining its insensitivity to eye movements. Crowding distance with Pelli optotypes was measured for trigrams and three repeated arrangements (single-line, single-line-with-bars, full-screen) in 28 normal healthy children (3 to 11 years) and 6 adults. The spacing to width ratio was 1.4x, so size covaried with spacing. Visual acuity was measured using isolated Sloan letters. A 9AFC paradigm with QUEST procedure estimated threshold centre-to-centre letter spacing and size. Crowding distance was also measured with trigram and single-line-repeated arrangements in over 40 amblyopic children and normal controls. Crowding distance decreases with age in normal children ($p < 0.05$), but no significant differences were found among the 4 different crowding distance tests ($p > 0.05$). Children found the single-line repeat test easier to perform than the full-screen repeat test, but crowding distances were not different (0.16 ± 0.03 deg vs. 0.16 ± 0.03 deg). Crowding distance was 3.4x larger in amblyopic children at 0.32 ± 0.10 deg vs. 0.09 ± 0.02 deg in normal healthy children. Acuity letter size was only 2.8x larger in amblyopic vs. normal children. Crowding distance was successfully measured using trigrams and a single-line repeat arrangement in young normal, and amblyopic children. Amblyopia increases crowding distance in children. Future work will test sensitivity of measures to changes with treatment, development, and amblyopia type.

Poster Session B > Spatial Vision: Crowding > Poster B7

How crowding challenges (feedforward) convolutional neural networks

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Are (feedforward) convolutional neural networks (CNNs) good models for the human visual system? Here, we used visual crowding as a well-controlled psychophysical test to probe CNNs. Visual crowding is a ubiquitous breakdown of object recognition in the human visual system, whereby targets become jumbled and unrecognisable in the presence of flanking objects. Humans exhibit several well-documented effects of crowding, such as invariance to size, where the size of the target and flanker letters may be changed without impacting the strength of crowding. We show that feedforward CNNs are unable to reproduce invariance to size, confusion between target and flanker identities, and importantly uncrowding, where paradoxically increasing the number of flankers improves performance. We investigate this phenomenon using a recurrent, neurally inspired model called LAMINART, which we find can reproduce uncrowding as observed in humans. Furthermore, we show that capsule networks, a recurrent family of CNNs with grouping and segmentation mechanisms, outperform any other models of uncrowding to date, demonstrating the importance of grouping and segmentation in mechanisms in visual information processing in general.

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Poster Session B > Spatial Vision: Crowding > Poster B8

Modulation of fixational eye movements during visual crowding

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Even during fixation, our eyes are not perfectly steady but instead make small-scale eye movements (microsaccades) that have been proposed to be task related. Large intentional saccades to a peripheral target that is crowded (surrounded by flankers) have been shown to reduce the harmful effects of crowding. However, the impact of fixational eye movements (FEM) on crowding remains unknown. Here, we investigated fixational eye movements when performing a crowding task. A tracking scanning laser ophthalmoscope (TSLO) with a 3° raster and an 840 nm imaging beam was used to image the right eye of each observer (4 males and 1 female with normal ocular health) during a psychophysical task. Stimuli were presented on an LCD display (screen size of 62.5 cm, 1920 X1080 pixels) optically overlaid with the imaging raster. The stimuli consisted of Sloan numbers (0-9) presented for 100 ms, either unflanked or surrounded by Sloan numbers at one of 4 nominal spacings. This was repeated for eccentricities 1 through 5 degrees, with sizes scaled to provide 75% performance in the unflanked condition at each eccentricity. Strip-based cross-correlation was used to retrieve eye motion from the retinal videos. 480 retinal videos (2 minutes each) were analyzed, from which 48,533 microsaccades were detected. Strong suppression of microsaccades was observed 150 ms following stimulus onset. Interestingly, in the critical period between 150 and 250 ms following stimulus onset, average microsaccade amplitudes systematically decreased as eccentricity increased (0.014°/degree of eccentricity). When flankers were absent or at the largest spacing, directional congruency of microsaccades in relation to the target in the 200-400 ms time bin was predictive of behavioral performance, but this effect was abolished when flankers were closer in. We found that in a peripheral flanked identification task, performance-related microsaccadic activity was less pronounced for crowded stimuli.

Spatial Vision: Models

Poster Session B > Spatial Vision: Models > Poster B10

The Energy-Normalized MAX Observer Approximates the Ideal Observer Under

High-levels of Simultaneous Orientation and Scale Uncertainty in White Noise

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When detecting targets under natural conditions, the visual system almost always faces multiple, simultaneous dimensions of extrinsic uncertainty. Many of these dimensions (like orientation and scale) result from random variation in object pose or observer viewpoint. To understand the fundamental limits to performance set by simultaneous dimensions of uncertainty, it is useful to determine the performance of ideal observers, which provide the appropriate benchmark for evaluating the performance of human observers and sub-optimal model observers. Unfortunately, even for a small number of dimensions, simulating ideal-observer performance can be prohibitively time consuming. We describe an efficient method for simulating the effects of high levels of uncertainty on detection of additive targets in white noise backgrounds. This method is based on equations that make it possible to precompute many of the quantities needed in the simulation of ideal and sub-ideal observers. We demonstrate the method by simulating the exact ideal observer, and the maximum-template-response (MAX) observer, with the simultaneous extrinsic uncertainty about the target scale and 2D orientation. The task is to detect a target which might appear in any of 359 different orientations and 51 different scales (total of 18,360 template shapes). The method was able to simulate 36,720 trials for the exact ideal observer in less than a minute, with an average office computer. (This is equivalent to simulating with 4 dimensions of uncertainty with 10 levels along each dimension.) For various single dimensions of uncertainty, the MAX observer has been shown to closely approximate the ideal observer. Here, we find it approximates ideal performance only if the templates are normalized by their total energy. When not properly normalized, the hit rate of MAX observer as a function of scale systematically deviates from that of the ideal observer. We are currently testing these predictions in psychophysical experiments.

Acknowledgements: NIH grant EY024662

Poster Session B > Spatial Vision: Models > Poster B11

Consequences of Eye's Optics and Geometry for Retinal Image Motion

View Poster | Visit me in Gather.Town Osprey Room on Sunday 8:00 am - 10:00 am EDT

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A substantial body of evidence supports the long-standing hypothesis that the visual system uses luminance modulations from eye movements to encode spatial information in the temporal domain. For simplicity, eye movements are commonly assumed to translate the image across the retina consistently, yielding luminance modulations with uniform statistics across the visual field. However, in reality, the optics and kinematics of the eye interact to yield a more complex pattern of image motion. Here we show that these considerations may have functional consequences for neural encoding and emmetropization. Using a detailed optical model of the rotating eye with a non-spherical retina, we examined two conceptually separate but geometrically related factors that contribute to retinal image motion: (1) Optical distortion, the mapping of visual space onto the retina, which is influenced by the eye's refracting properties; and (2) motion transfer, the amount of motion at each point of the retinal image, which depends on the eye's center of rotation. In an emmetropic eye accommodated to infinity, we find that retinal image motion increases nonlinearly across retinal eccentricity, with ~30% greater retinal image speed in the periphery compared to the fovea. This effect implies that the characteristics of luminance modulations induced by eye movements also vary with eccentricity. Specifically, during fixation, luminance modulations will deliver increasingly more power at low spatial frequencies as eccentricity increases. This transformation is altered in non-emmetropic eyes due to differences in eye shape, with each diopter of spectacle refraction resulting in a ~3% change in peripheral retinal image motion. Since there is greater motion in hyperopic eyes and less motion in myopic eyes relative to emmetropic eyes, the statistics of image motion provide a cue to the sign of blur, which can be accessed from the temporal content of neural signals.

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Poster Session B > Spatial Vision: Models > Poster B12

Visual Information Fidelity with better Vision Models and better Mutual Information Estimates

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INTRODUCTION: Visual Information Fidelity [1] is a subjective image distortion measure based on: (i) a noisy observer model, and (ii) a method to quantify mutual information. Specifically, given two images A (original) and B (distorted), and their responses through the model R(A) and R(B), the visual fidelity is defined as the ratio between the amount of information about A that can be extracted from R(B) and the corresponding amount that can be extracted from R(A). The information about X that is available from Y is quantified via the mutual information, I(X,Y). Therefore: VIF(A,B) = I(A,R(B)) / I(A,R(A)). The original VIF used a too crude vision model (linear wavelet pyramid + Gaussian noise) and a too crude mutual information estimate (based on a simplified image statistics model). In this work we explore how better vision models and better information measures may lead to a better explanation of image quality psychophysics. *METHODS*: we improve the linear vision model in original VIF by using divisive normalization stages for brightness and contrast masking [2], we use a more accurate psychophysical estimate of neural noise [3], and an estimate of mutual information that does not rely on parametric assumptions [4]. *RESULTS AND CONCLUSION*: the correlation with human opinion with images from the TID-2008 database improves from 0.78 (using the original formulation of VIF) up to 0.90 using some of the proposed improvements. This suggests that an appropriate consideration of the neural noise and a non-parametrical measure of mutual information are critical in assessing subjective image quality. *REFERENCES*: [1] H. Sheikh, A. Bovik. IEEE Trans. Im. Proc., 15(2):430–444, 2006 [2] M. Martinez, P. Cyriac, T. Batard, M. Bertalmío & J. Malo. PLOS ONE, 13(10):1–49, 10 2018. [3] J.Esteve, G.Aguilar, M.Maertens, FA.Wichmann & J.Malo. https://arxiv.org/abs/2012.06608, 2020 [4] J. Malo. J. Math. Neurosci., 10, 18 (2020). https://doi.org/10.1186/s13408-020-00095-8

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Visual Memory: Neural mechanisms

Poster Session B > Visual Memory: Neural mechanisms > Poster B13

Contralateral delay activity and induced alpha power are modulated by memory load independently of stimulus eccentricity in a virtual reality setup

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Combining virtual reality (VR) with EEG and eye-tracking offers new possibilities for the investigation of cognitive processes. It is unclear to what extent established findings from studies using conventional monitors translate to setups using VR head-mounted displays. Here, we assessed whether EEG markers of visual short-term memory load, the evoked-response amplitude of the contralateral delay activity (CDA) and the power of induced alpha oscillations, can be replicated with VR glasses and whether they depend on the horizontal eccentricity of the stimulus in the visual field. We tested observers' visual memory in a delayed match-to-sample task with bilateral stimulus arrays of either two (low memory load) or four (high load) coloured circles. Moreover, we varied the horizontal eccentricity of the stimulus arrays (either 4, 9 or 14 degrees of visual angle). At the beginning of each trial, we displayed a cue informing observers which array (left or right from fixation) would be probed in the later memory test. We presented the stimulus arrays for 200ms, followed by a retention interval of two seconds. Simultaneous eye-tracking allowed us to include only trials without saccadic eye movements in the final analyses. Observers' memory performance was better for low as compared to high memory load—irrespective of stimulus eccentricity. Both, CDA amplitude and alpha power during retention, increased significantly with memory load across all eccentricities. We further corroborated these findings by fitting time-resolved spatial filters to decode memory load from voltage as well as time-frequency data. Classification accuracy during the

retention interval was above chance level for both, the evoked potential and induced alpha power, and did not vary significantly across eccentricities. We conclude that memory load effects on CDA amplitude and alpha power can be shown using commercial VR glasses and for stimuli with horizontal eccentricities of up to 14 degrees of visual angle.

Poster Session B > Visual Memory: Neural mechanisms > Poster B14

Decoding visible and memorized stimulus features from neuronal ensembles in the prefrontal and visual cortices

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A long-standing question in neuroscientific research is how sensory information is encoded and maintained in working memory (WM). Although converging evidence has suggested that activity in the prefrontal cortex (PFC) is critical for WM, the contribution of distinct regions within the PFC in the retention of behaviorally relevant visual features is unknown. Furthermore, it has been recently suggested that PFC processes higher-order information, whereas feature-specific information is rather retained in visual areas. To address these questions, we performed simultaneous extracellular recordings from the ventral prearcuate area (VPA), the frontal eye field (FEF) and visual area V4 in two monkeys engaged in a cued attention task. In each trial, information about the location or color of the upcoming target was provided by a spatial/color cue that had to be memorized. To estimate the location/color information carried by neuronal ensembles in the different areas, we applied machine learning approaches to spiking and local field potential (LFP) activity. Our results suggest that PFC neuronal ensembles encode and retain in WM spatial and color information in an anatomically-specific manner. Higher decoding accuracies were obtained from the FEF population for spatial information, whereas color information was decoded more robustly from VPA during the cue and delay periods. Moreover, we found that the population code for color identity changed during the delay period in VPA. Interestingly, a subset of V4 neurons with non-central RFs also carried spatial and color information in their firing patterns during the delay. An LFP analysis indicated that spatial information can be robustly decoded from both areas from high-gamma and beta LFP bands, whereas color information can be reliably decoded from VPA only. Altogether, our results shed light into the functional anatomy of WM in the prefrontal and visual cortices.

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Poster Session B > Visual Memory: Neural mechanisms > Poster B15

Dissociating the impact of stimulus memorability and encoding success on EEG correlates of visual long-term memory encoding

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Our ability to encode information into our visual long-term memory (VLTM) fluctuates due to many factors. These factors include individual specific fluctuations in cognitive states that contribute to the likelihood of encoding success (e.g., sustained attention; deBettencourt et al., 2018) and stimulus-intrinsic properties that determine the ease of encoding across individuals (e.g., memorability; Bainbridge et al., 2017). We seek to define how these distinct encoding success factors relate to the several existing dissociable electrophysiological markers (frontal positivity, occipital alpha power, and frontal theta power) sensitive to memory encoding success (e.g., Fukuda & Woodman, 2015; Zhao & Woodman, 2020). Thus, we measured participants' EEG while they encoded the same set of 600 pictures of real-world objects (Brady et al., 2008) into their VLTM. Here we first replicated that some pictures were consistently better remembered than other pictures across participants, thus verifying their memorability. Next, we split the pictures into "memorable" and "forgettable" pictures via median split based on collective memory performance and examined the sensitivity of each electrophysiological marker to individual-specific memory encoding success (i.e., correctly recognized vs. missed) in

each picture group. For frontal positivity, a repeated-measures ANOVA revealed significant main effects of memorability and encoding success. For occipital alpha power, we found a significant main effect of encoding success as well as a significant interaction between memorability and encoding success. These results demonstrate that frontal positivity and occipital alpha power are sensitive to both stimulus-intrinsic memorability and individual-specific encoding success with dissociable patterns. For frontal theta power, we only found a significant main effect of encoding success, thus revealing frontal theta power's selective sensitivity to individual-specific encoding success. Together, our results support the idea that memory encoding is a multifaceted process by linking distinct encoding success factors to putative neural markers.

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Dissociation between eye position and working memory signals during virtual reality tasks in the primate lateral prefrontal cortex

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Neurons in the primate lateral prefrontal cortex (LPFC) maintain working memory (WM) representations of space. However, a proportion of LPFC neurons also encode signals related to eye position. Potential interference between eye related signals and WM representations has prompted strict control of eye position in traditional WM tasks. Therefore, it is unclear how unrestrained eye position may affect performance of a WM task and task related LPFC activity. To explore this, we trained two rhesus monkeys on a spatial WM task set in a naturalistic virtual environment. During task trials, a target was presented at 1 of 9 locations in the environment. The target then disappeared during a two second delay epoch, after which the animals were required to navigate to the cued target location using a joystick. Animals were permitted free visual exploration throughout the task. We recorded neuronal activity using two 96-channel Utah Arrays implanted in LPFC area 8ad/v. Even with unrestrained eye position, animals only spent 3.6% of total fixation time during the delay period looking at the target location. The duration in which animals looked at the target location did not influence trial outcome (Kruskal Wallis, $p=0.151$). We tested whether neuronal population activity during fixations could predict eye position on targets. Classifiers using neuronal population activity during fixation periods were unable to decode eye position above chance (T-Test, $p=0.646$). Moreover, we calculated the proportion of neurons tuned for saccade landing position in different reference frames. Only 2% of neurons were tuned for both target location and saccades in the retinocentric frame and 3% were tuned for target location and saccades in the spatiocentric frame. These results indicate that in a virtual environment, unrestricted eye position does not diminish performance on a spatial WM task. Results suggest a dissociation between eye position and WM signals within LPFC.

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Embracing New Techniques in Deep Learning for Predicting Image Memorability

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Various work has suggested that the memorability of an image is consistent across people, and thus can be treated as an intrinsic property of an image. Using computer vision models, we can make specific predictions about what people will remember or forget. While older work used a now-outdated deep learning architecture to predict image memorability, innovations in the field have given us new techniques to apply to this problem. Here, we propose and evaluate five alternative deep learning models to MemNet which exploit developments in the field from the last five years, largely the introduction of residual neural networks. We also evaluate the pre-existing implementation of MemNet on a broader set of images. Five new models with architectural differences were implemented and tested on a mixture of MemNet's original training set, LaMem, and a recent dataset, MemCat. LaMem is a large database of objects and scenes, many of which are designed to have high memorability. MemCat complements this, with a large number of exemplars in object categories. The new models all utilize residual neural networks, which are intended to mimic the structure of pyramidal cells with skip connections, in their feature extraction stages, allowing the model to use semantic information in the

memorability estimation process. The most complex model also utilizes semantic segmentation, which ascribes a semantic category to each pixel. Our findings suggest that the original paper overstated MemNet's generalizability and MemNet likely was overfitting on LaMem. Our new models outperform MemNet, all achieving similar scores to one another, but when allowed to retrain the semantic segmentation based model outperforms the rest. This information leads us to conclude that Residual Networks outperform simpler convolutional neural networks in memorability regression, which will in turn improve memory researchers' ability to make predictions about memorability on a wider range of images.

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Ruling out a role for oscillatory coupling of frontal theta and posterior alpha in visual long-term memory encoding

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Given that visual memories are stored in regions spanning the cortex and subcortex, visual memory encoding is one of the most likely cognitive processes to rely on the coordinated coupling of activity through the synchronization of neural oscillations. Previous research suggests that decreasing posterior alpha power and increasing mid-frontal theta power individually contribute to better visual long-term memory encoding. Naturally, a possible explanation for this observation would be that the frontal theta enhancement and posterior alpha suppression form a coherent network for successful memory encoding in which the higher frequency alpha activity is coupled to the slower theta carrying wave. Contrary to this hypothesis, here we show that neither the amplitude-amplitude coupling nor the phase-amplitude coupling between frontal theta and posterior alpha appears underlie observers' ability to encode pictures into long-term visual memory. First, we found that the strength of coupling was not predictive of observers' subsequent memory recognition ability. Second, the theta-alpha coupling relationships were not modified by anodal transcranial direct current stimulation over temporal lobe, despite brain stimulation improving memory for pictures of objects. Third, when we measured raw correlations between alpha and theta power, we discovered that posterior alpha power and frontal theta power were more tightly correlated during eyes-open resting state than during memory encoding, when the coordination between theta and alpha breaks down. Together, these findings show that posterior alpha and frontal theta power are individually related to visual long-term memory encoding, but this is not due to large scale coupling between these brain oscillations.

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Understanding how analysis choices are essential for the meaningful interpretation of visual working memory data

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Visual working memory (VWM) relies on a distributed cortical network. Yet, the role of individual cortical areas, like early visual cortex (EVC) and intraparietal sulcus (IPS), remains debated. Criteria have been suggested to determine if an area is essential for storage, such as resiliency against visual distraction, and correlations with behavior. Here, we reanalyzed existing data from two independent labs, and caution that adherence to simple criteria could limit our

comprehension of the VWM system. Instead, we encourage close consideration of analysis choices for a more complete perspective. When participants remembered an orientation while simultaneously viewing different visual distractors (Rademaker et al., 2019) fMRI activity patterns in EVC and IPS did not distinguish between distractor conditions. While such resiliency implies that both areas are critical for VWM storage, the analysis used (leave-one-out cross-validation) capitalizes on any signal differentiating memory representations during the delay. Instead, an analysis using sensory driven responses for model-training captures only representations that are “sensory-like”, and can yield different conclusions. That analysis choices matter is further illustrated by a task with two memory items – one attended, one unattended (Christophel et al., 2018). Originally, delay-period representations of unattended items were not found in EVC. Our reanalysis reveals that with a model trained on stronger signals (the attended instead of the unattended items) EVC does represent unattended memory items. Finally, both datasets reveal a brain-behavior relationship in EVC, but not IPS. Before declaring EVC essential to storage, a careful examination of analysis choices (like the quantification and read-out of neural error) should be performed to guide interpretation. In sum, a thorough understanding of analyses and the specific principles they test is crucial for unraveling the mechanisms of VWM.

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Poster Session B > Visual Memory: Neural mechanisms > Poster B20

Working Memory and Prefrontal Neural Activity of Macaques in Early Adolescence

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Humans and nonhuman primates experience a protracted period of cognitive development, and the accrual of cognitive capacities parallels the maturation of the prefrontal cortex (PFC). To characterize developmental improvements in visuospatial working memory and examine the underlying maturation of the PFC that enables it, we trained 8 adolescent macaques (2F, 6M) to perform variations of the Oculomotor Delayed Response (ODR) task, and recorded neural activity in the PFC at two time points, at the ages of 3.4±0.2 years and 4.0±0.2 years. Eight animals performed the ODR task with a 1.5 s delay, four animals performed a version of the task with a longer, 3 s delay period, and four animals also performed the ODR + distractor task, in which a distractor appears during the 3s delay. Overall performance in the ODR task (percentage of correct trials among trials completed) for the 8 monkeys was 78% in 301 sessions. Monkeys with lower average performance exhibited higher variability across sessions. Between the two time points, modest improvements in performance in the ODR task and ODR + distractor task was observed, with the greatest improvement for the most difficult tasks and conditions. Development between the two time points was characterized by an increase in the percentage of neurons that responded to the task (98/401= 24% and 84/261=32% respectively, chi-square = 4.76, p = 0.03). However, the firing rates of the neurons that did respond to the task were similar at the two time points (6.98 vs. 6.43 spikes/s for the delay period, 1-way ANOVA, p = 0.62). Our results provide insights on prefrontal neuronal activity during working memory at the earliest time points achieved and indicate progressively greater engagement of the prefrontal cortex as development advances.

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Poster Session B > Visual Memory: Neural mechanisms > Poster B21

Prefrontal gamma power and LFP tuning in working memory decrease during monkey adolescent development

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Working memory ability continues to mature into adulthood in both humans and non-human primates. At the single neuron level, adolescent development is characterized by increased prefrontal firing rate in the delay period, but less is known about how coordinated activity between neurons is altered. Local field potentials (LFP) provide a window into the computation carried out by the local network. To address the effects of adolescent development on LFP activity, three male rhesus monkeys were trained to perform an oculomotor delayed response task. The animals were required to remember a visual stimulus through a 1.5 second delay period and report with a saccade. They were then tested at both the adolescent and adult stage. Simultaneous single-unit spiking (adolescent N = 298, adult 392) and LFP (adolescent N = 130, adult 164) signals were recorded from areas 8a and 46 of the dorsolateral prefrontal cortex (dlPFC). In both the cue and delay period, power relative to baseline decreased in the beta frequency range (16 - 32 Hz) and increased in the gamma frequency range (32 - 128 Hz). However, the adult dlPFC had fewer sites with significant gamma modulation (63% vs. 88%, Fisher's exact test, $p < 0.001$). The adult dlPFC also showed weaker stimulus tuning in the low gamma range (32 – 64 Hz) as revealed by the percentage of explained variance. On the other hand, adult dlPFC neurons exhibited sharper delay tuning and elevated firing rate to the best location from 12.0 to 16.5 spikes per second (t-test, $p < 0.001$), predominantly at sites with significant LFP gamma power modulation and tuning. The results suggest a decrease in inhibitory neuronal interactions after adolescence, in agreement with previous reports for the monkey dlPFC, which leads to a decrease in gamma power and tuning to achieve improved working memory in adulthood.

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Distraction disrupts attentional filtering for visual working memory: Neural and behavioral evidence for the Filter Disruption Theory

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We navigate our visual environments via interactions between attention and visual working memory (VWM): When searching for a target, an early filter constrains attention to target-matching features and, in turn, attention filters VWM encoding to ensure relevant information is represented and used to guide behavior. When distracting (i.e., unexpected/salient) information appears, however, attention is captured, slowing visual search. Does distraction also disrupt ongoing attention/VWM interactions? Across two experiments we test the predictions of our Filter Disruption Theory: distraction disrupts the filters that typically prevent irrelevant information from being attended and stored in VWM. In E1 we measured filters tuned to object categories using fMRI: Participants viewed a 2x2 array of hybrid face/house images and performed a 1-back visual search task on one stimulus category (i.e., attend-faces or attend-houses blocks). The target image was defined by a solid white border, but on some trials, a salient distractor (a white dotted line) also appeared briefly around a nontarget image. On distractor-absent trials, we found the standard pattern of greater BOLD activation in fusiform face area (FFA) during attend-faces blocks and parahippocampal place area (PPA) during attend-houses blocks. However, on distractor-present trials, we observed a boost in activation for the nontarget category (e.g., increased FFA activity during attend-houses), suggesting a loss of control over both spatial attention and the attentional control filter tuned to object category, leading to incidental processing of the task-irrelevant category. In E2, we demonstrated behaviorally that the features of a salient distractor are also incidentally encoded into memory and can drive subsequent attention, even when those features are irrelevant to both the original and subsequent tasks. These data provide direct support for the Filter Disruption Theory, and more broadly suggest that distraction disrupts the interactions between attention and VWM.

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Sleep depth is represented in the early visual area: evidence from multivoxel pattern analysis

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Processing in early visual areas during sleep after visual training plays an important role in facilitating visual learning

(e.g., Tamaki et al., 2020, Nat Neurosci). However, the extent to which early visual areas are involved in processing sleep itself remains unclear. If the activation in an early visual area is largely related to a sleep status such as the depth of sleep, the activation in the area alone should predict the sleep depth to a significant degree. To test this hypothesis, we recorded functional magnetic resonance imaging (fMRI) activation patterns in V1 while participants were asleep (90 min) simultaneously with polysomnography in multiple sessions and examined whether sleep depth, shown as a sleep stage, is decodable from the multivoxel fMRI patterns in V1. The middle frontal gyrus (MFG) was used as a control region, since MFG is thought to originate slow waves, which are EEG waves that occur specifically during sleep, and thus to be sensitive to sleep depth. A binary sleep-stage classifier on multivoxel fMRI patterns was constructed to classify fMRI patterns from each V1 and MFG into wakefulness and NREM stage-2, a sleep stage whose onset is often regarded as a sleep onset. Subjects' being in wakefulness and NREM stage-2 were determined by polysomnography independently from fMRI patterns. To avoid the circular analysis (Kriegeskorte et al., 2009), we trained the sleep-stage classifier based on the dataset obtained on the second (or third) day and applied the classifier to the dataset on the first (or second) day. We found that the classification accuracy from fMRI patterns in V1 was significantly higher than the 50% chance level, but not from those in MFG. These results indicate that the activation in V1 alone discriminates an important sleep stage from wakefulness, suggesting a great involvement of V1 in sleep depth.

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Visual Memory: Imagery, drawing, scenes

Poster Session B > Visual Memory: Imagery, drawing, scenes > Poster B24

Attention to Absences

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You return to your locked-up bicycle and immediately notice that the front wheel is missing. (Oh no! It must have been stolen.) As you stare at your incomplete frame, you have a visceral sense of the wheel's *absence*; there isn't just empty space where the wheel should be — there is a missing wheel. What is the nature of this experience? Whereas we typically think of perception and attention as being directed toward (present) objects, here we explore attention to missing or absent parts. Six experiments show that regions of space with missing parts ("absent space") are processed differently than more ordinary empty regions ("empty space"). Subjects saw line drawings of objects missing a part (e.g. a bicycle missing a wheel, a butterfly missing a wing, a jacket missing a sleeve, etc.), and then judged whether a probe appeared on the object or not. Intriguingly, when non-object probes appeared in absent space (e.g. where the front wheel should have been), subjects classified them faster than when probes appeared in empty space (e.g. next to the bicycle). We found this effect with spatially adjacent probes (E1), probes distributed around the stimulus (E2), and when subjects had to discriminate the probe's color instead of its position (E3 & E4), suggesting that "absent" space attracts attention automatically and efficiently. In contrast, no reaction-time difference was found with scrambled images (destroying the appearance of absence), even though the images' low-level features and the probes' relative positions were preserved (E5). Finally, the absent-part attentional benefit was lost when stimuli were placed closer to the border of a bounding box to create the impression that the absent part couldn't "fit" (E6). We conclude that, despite not being "objects" at all, absences are prioritized over otherwise identical empty spaces by mechanisms of perception and attention.

Poster Session B > Visual Memory: Imagery, drawing, scenes > Poster B25

Does mental imagery vividness predict memory performance?

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Visual mental imagery, or the ability to see with the mind's eye, varies between individuals. The vividness of a mental image ranges from aphantasics who experience no mental image at all, to hyperphantasics who experience extremely vivid and clear mental imagery. The present study aims to investigate the possible connection between the vividness of visual mental imagery and precision of information retrieved from visual memory. We predicted that individuals who experience weak or no mental imagery are poorer at retrieving information with great details from memory, such as the color of objects, than those experiencing strong and vivid mental imagery. This was tested in three experiments: a visual perception task, a visual working memory task, and a visual long-term memory task. In addition, participants were asked to complete a questionnaire used to measure the vividness of mental imagery. The perception task served as a control task where two identical objects were presented simultaneously, a colored sample object and a grayscale test object. In the working memory and long-term memory tasks, a delay was added between the presentation of colored sample objects and grayscale test objects. A color-wheel was located around the grayscale test object and was activated by moving the mouse. Participants were asked to adjust the color-wheel until the test object's color matched that of the corresponding sample object. Our findings indicate no association between mental imagery vividness and memory precision. Possible explanations for this lack of an association are discussed.

Poster Session B > Visual Memory: Imagery, drawing, scenes > Poster B26

Exploring individual differences in neuropsychological and visuospatial working memory task performance in aphantasia

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Aphantasia describes the newly-identified experience of individuals who self-report a lack of voluntary visual imagery. Individuals with aphantasia are typically identified via subjective introspection on imagery experience, a process that has been shown to be modulated by personality traits. It is also not clear whether individuals with aphantasia show broader cognitive deficits or differences within other memory domains, which may explain their self-reported lack of visual imagery. This research examines group and individual differences within individuals with aphantasia on a battery of tests: a personality scale, a range of standardised neuropsychological tests of cognitive function and two visuospatial working memory tasks. Twenty individuals with congenital aphantasia (VVIQ < 25) were identified and matched on measures of age and IQ to twenty individuals with typical imagery (VVIQ > 35). Within the personality tests, the groups differed only for agreeableness, possibly resulting from a sampling bias. Similarly, the only group differences in the neuropsychological and visuospatial cognitive tests were slower performance in a task during trials that had greater working memory load, and larger variability in response times for front/back orientations within an egocentric perspective-taking task. Nevertheless, exploratory individual differences examination of performance using multidimensional scaling (which groups participants' performance across all measures in terms of the level of similarity or dissimilarity) identified four aphantasic subgroups, each of which exhibited differing performance. In summary, these results suggest that the personality and cognitive profile of people without imagery do not greatly differ from those with typical imagery when examined by group. However, observed group differences were apparent with increased working memory load. Subgroups of aphantasia were identified, suggesting that some aphantasic individuals may experience more specific cognitive deficits. Further research should investigate the processes adopted by these subgroups, or whether (or not) individuals with aphantasia have unconscious mental imagery.

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Poster Session B > Visual Memory: Imagery, drawing, scenes > Poster B27

Matter over mind: Effects of imagery and perceptual priming on visual attention

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Visual mental imagery has been shown to guide attentional selection, but how that compares with visual perception remains unclear. We primed participants by having them focus on the color of a presented square or instructed them to visualize the prompted color in an empty square before every trial. In Experiment 1, participants went on to perform a shape singleton search task where the primed color could serve as target or distractor. In Experiment 2, participants went on to perform a color-word Stroop task where incongruent Stroop stimuli were presented; the hue or word incidentally coincided with the primed color. We found that perceptual priming was stronger than visual imagery priming

for both experiments. In Experiment 1, we found a main effect of validity (valid vs. invalid with respect to the prime and subsequent target color) and an interaction between validity and prime type (perceptual vs. imagery). A significant validity effect was observed for each prime type, although it was larger for perceptual primes. With respect to hue in Experiment 2, there was again a significant interaction between validity and prime type, although in this case the validity effect was individually significant only for perceptual primes. Neither type of prime influenced word processing, although there was a marginally significant validity effect for perceptual primes. Taken together, our results suggest that perceptual priming is generally stronger than priming by visual imagery. The influence of imagery primes appears to be restricted to lower-level visual processing, while perceptual priming was evident in both tasks. All data collection was conducted online using JavaScript, JsPsych and JATOS to interface with SONA. A follow-up experiment will compare visual imagery and perceptual priming on visual search for complex, real-world objects.

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Poster Session B > Visual Memory: Imagery, drawing, scenes > Poster B28

Parallel neural representation shared by visual perception and mental imagery

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Visual mental imagery and visual perception have been shown to share a hierarchical topological visual structure of neural representation. However, despite many studies demonstrating that mental imagery involves the top-down modulation perceptual processes, we have limited knowledge about how during perception internally generated mental imagery integrate with the outside input stimuli. Here we used the dataset from previous fMRI research (Horikawa & Kamitani, 2017), which included a visual perception and an imagery experiment with human participants. We trained two types of voxel-wise encoding models, based on Gabor features and activity patterns of high visual areas, to predict activity in early visual areas (V1-V3) during perception, and then evaluated the performance of these models during mental imagery. Our results showed that during perception, activity in early visual areas could be independently predicted by the Gabor features and activity of high visual areas from encoding models, which shared with mental imagery. We further found that there existed a Gabor-specific and a non-Gabor-specific neural response pattern to stimuli in early visual areas, which paralleled a representation of the stimuli relevance information. These findings provide insights into mechanisms of how our brain integrates external and internal information.

Acknowledgements: National Natural Science Foundation of China 31600907

Poster Session B > Visual Memory: Imagery, drawing, scenes > Poster B29

Intuitive physics does not rely on visual imagery

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From reaching for a glass of water to driving a car, interactions with the physical world are ubiquitous in our lived experience. To plan our actions, we must anticipate how objects will behave as they interact under physical constraints —an ability termed “intuitive physics”. A flurry of ongoing work is seeking to uncover the mental algorithms underlying intuitive physics, and one prominent view holds that we carry out mental simulations to predict physical dynamics, stepping forward through successive states of the world as we anticipate how physical interactions will play out. Recent evidence from both brain imaging and behavior supports the notion that we use mental simulation in at least some cases (although this remains debated), raising the question of what format these simulations have in the mind. Do mental simulations play out in a strictly symbolic sense, or might they rely on visual imagery as a workspace? Here, we asked whether physical prediction relies on “seeing” dynamics unfold in the mind’s eye. In 200 online participants, we characterized individual differences in the vividness of visual imagery using two well-established self-report measures, and we tested intuitive physics performance using a set of three tasks: predicting the path of a ball rolling over hills, judging how an unstable block tower would fall, and deciding whether an oncoming ball would knock a block off a platform. We found substantial and reliable individual differences in the vividness of visual imagery and in performance on the intuitive physics tasks, but there was no relationship between visual imagery and intuitive physics. Many of those

who reported little or no subjective imagery aced the physics tasks nonetheless. Our results show that the subjective vividness of visual imagery has no bearing on physical prediction abilities, and mental simulations of physical dynamics happen outside of the mind's eye.

Poster Session B > Visual Memory: Imagery, drawing, scenes > Poster B30

Drawing ability correlates with visual memory performance

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In visual memory research, recognition tasks are commonly used to query memory. However, the recent emergence of drawing as a visual free recall task has allowed for a new ability to quantify detail and content within visual memory. A still open question with these paradigms is the degree to which differences in memory performance are related to drawing ability. In this study, we conducted an experiment where twenty participants were asked to memorize a randomized series of 20 scenes counterbalanced for memorability. Participants performed a digit span distractor task, and then were asked as a surprise recall task to draw all presented images. Finally, they were tested for visual recognition of the original 20 scenes intermixed with 20 matched foils. Participants showed high recognition performance (average accuracy 92%) and moderate recall performance (16.6 drawings from memory on average). After this main experiment, twenty raters were recruited to rank these drawings based on the quality of the drawing (without knowledge of the original scene) and the quality of the memory representation (with knowledge of the original scene). Participants showed large interindividual differences in drawing ability that were consistent across their drawings. The rated quality of their memory representations was significantly correlated with their recall performance (Spearman's ρ=0.42), their recognition performance (ρ=0.41), and their general drawing ability (ρ=0.86). However, there was also a significant correlation between ratings of their drawing ability and both recognition performance (ρ=0.86) and recall performance (ρ=0.41). The correlation between recognition performance accuracy and recall performance was small (ρ=0.08). Taken together, these results reveal a relationship between drawing skill and the quality of visual memories, tested through both recognition and recall, highlighting a potential influence of learned strategies on visual memory abilities.

Acknowledgements: The research has been supported by Czech Science Foundation (GA19-07690S)

Poster Session B > Visual Memory: Imagery, drawing, scenes > Poster B31

Drawings reveal accurate visual information in memory after just 100 ms of exposure

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When we view an image for the first time, we rapidly capture its gist, followed by more detailed visual information. Most studies have employed visual recognition or verbal recall tasks to quantify the contents within the gist and details of a visual memory. However, utilizing drawings as a memory measure could reveal more about these representations and their timescales. Here, we conducted three different experiments through Amazon Mechanical Turk to test gist and detail content through drawn memories. The main experiment consisted of a drawing task, where participants (N=120) were exposed to real-world scene images for different lengths of time, varying from 100 ms to 10,000 ms. After a 500 ms delay, they were then asked to draw the image from memory in as much detail as possible. Drawings were monetarily rewarded based on number of objects present in their drawings, to motivate participants. Two separate scoring experiments asked for different participants to determine whether drawings included objects present in the original stimulus (N=410), and whether there were false object insertions not present in the original stimulus (N=91). First, we observed that participants were able to successfully complete memory drawings across all time scales, with no differences in number of successful drawings between the 100 ms and 10,000 ms conditions. Second, false objects were found to be rarely present, with only one false object added to drawings on average in the fastest condition of 100 ms. However, we also observed that more correct objects were drawn from memory in the longest exposure condition, 10 seconds, for all tested images, and retention drastically improved for exposures greater than 500 milliseconds. In sum, while people were generally quite good at conveying the gist of the image at all presentation time scales, the exact

accuracy of their stimulus recreation improved with longer exposures.

Poster Session B > Visual Memory: Imagery, drawing, scenes > Poster B32

Effects of prior knowledge on memory for objects in real-world scenes: Schema violations benefit memory and metacognitive performance

View Poster | Visit me in Gather.Town Osprey Room on Sunday 8:00 am - 10:00 am EDT

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There has been a debate as to whether information that complies with our prior knowledge is better remembered than incongruent information. We aimed to investigate whether schema violations disturb or enhance memory for objects embedded in real-world scenes. We considered recognition performance as well as metacognitive judgements, i.e. the ability to judge the quality of memory decisions. A total of 272 participants took part in our study, which was implemented on the online platform Testable. In a learning phase, participants were presented 60 real-world scenes taken from the SCEGRAM database, containing target objects that were either semantically congruent or incongruent with the scene context (a mug in the kitchen versus in a bathroom). After a delay period of about 20 minutes, participants were asked to indicate for each of the 60 target and additional 60 new distractor objects whether it had been presented during the learning phase. Subsequently, a confidence rating about their decision was obtained. Based on signal detection theory, we assessed recognition performance for schema-congruent and schema-incongruent objects, respectively, by deriving d' as a sensitivity index and the criterion, i.e. the response bias. Metacognitive sensitivity was evaluated using meta-d'. Our data showed that object memory was significantly better for schema-incongruent targets than for schema-congruent targets. We observed overall conservative response biases, however, decisions were less biased for schema-incongruent targets. Thus, our results indicated that schema violations boost memory performance. Furthermore, analysis of meta-d' indicated higher metacognitive sensitivity for judging the quality of memory decisions on schema-incongruent targets. We suggest that schema violations in real-world scenes enhance processing of incongruent information and thus augment encoding as well as metacognition during retrieval. In conclusion, our findings support that violationsof prior knowledge do not necessarily interfere with object memory, but benefit memory for real-world scenes.

Acknowledgements: This work was funded by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG), Collaborative Research Centre SFB/TRR 135: Cardinal Mechanisms of Perception, project number 222641018.

Poster Session B > Visual Memory: Imagery, drawing, scenes > Poster B33

Fast, fleeting, and memorable: The link between image memorability and the perception of time

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Across a lifetime, each person encounters a vast miscellany of visual stimuli. Some of these images stick firmly in our memories, while others drift away with ease. This distinction lies in an image's memorability, an intrinsic quality that is steady across observers despite individual differences (Bainbridge, 2019). At the same time, images have the potential to grab our attention in a way that makes time fly by, or they can feel everlasting. In this experiment, we sought to uncover the relationship between image memorability and the perception of time passing, asking whether memorable images seem to last longer or shorter than their forgettable matches. To investigate the differential effects of image memorability on the perception of time, participants (N = 30) on Amazon Mechanical Turk were shown a total of 80 randomly ordered images for a range of durations, and were asked to mimic the durations of these images by holding down the space bar for the same duration. Each subject viewed 40 image pairs, consisting of memorable and forgettable stimuli in a variety of scene categories (including natural/manmade and indoor/outdoor scenes), and each memorable–forgettable pair was assigned one of eight durations, ranging in equal intervals from 500 ms to 4000 ms. It was observed that participants generally overestimated image durations below 2000 ms and underestimated durations above 2000 ms. The results of our study also suggest a trend in which highly memorable images produce shorter participant responses

than their less memorable counterparts. Deeper investigation into these images promises to reveal the specific factors that drive the perception of time. Thus, in our most memorable settings, time is fleeting more than ever.

Poster Session B > Visual Memory: Imagery, drawing, scenes > Poster B34

Scene grammar facilitates object-location binding in realistic scenes

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Every day we encounter various objects in various places: whether it be morning coffee on the table, fresh pizza in the microwave, or clothes scattered around the room. Studies demonstrated that swap errors could occur in VWM - incorrect binding of object and location information. However, in realistic scenes, attention is guided to specific locations under the specific scene laws. Thus, this study aimed to examine how scene grammar could influence object-location binding. We conducted an experiment where subjects memorized locations of objects presented in scenes. Real-world objects and realistic scenes were used as stimuli. Three objects in the scene were presented for 1 second, and after 1 second participants had to choose which object was presented at the marked location. There were two conditions: 1) target object had a position according to scene rules (e.g., pillow on the bed), and both distractors - against scene rules; 2) the target object had a position against scene rules (e.g., pillow on the floor), one distractor was in a consistent position (e.g., an alarm clock on the bed table) and another distractor was on the position which target object should have according to the scene grammar (e.g., slippers on the bed). The results showed that less errors were made in the condition where the target had position according to scene rules. Additional analysis of incorrect answers for the second condition demonstrated no difference between choosing the distractor which was located on the target's location according to scene rules and choosing the second distractor. Errors did not follow location expectations, thus, errors probably occurred during the encoding or storing stage and not during the response. We suggest that scene grammar strengthens object-location binding via proper attention guidance.

Poster Session B > Visual Memory: Imagery, drawing, scenes > Poster B35

Perception of soft materials relies on physics-based object representations: Behavioral and computational evidence

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When encountering objects, we readily perceive not only low-level properties (e.g., color and orientation), but also seemingly higher-level ones -- some of which seem to involve aspects of physics (e.g., mass). Perhaps nowhere is this contrast more salient than in the perception of soft materials such as cloths: the dynamics of these objects (including how their three-dimensional forms vary) are determined by their physical properties such as stiffness, elasticity, and mass. Here we argue that the perception of cloths and their physical properties must involve not only image statistics, but also abstract object representations that incorporate "intuitive physics". We do so by exploring the ability to *generalize* across very different image statistics in both visual matching and computational modeling. Behaviorally, observers had to visually match the stiffness of animated cloths reacting to external forces and undergoing natural transformations (e.g. flapping in the wind, or falling onto the floor). Matching performance was robust despite massive variability in the lower-level image statistics (including those due to location and orientation perturbations) and the higher-level variability in both extrinsic scene forces (e.g., wind vs. rigid-body collision) and intrinsic cloth properties (e.g., mass). We then confirmed that this type of generalization can be explained by a computational model in which, given an input animation, cloth perception amounts to inverting a probabilistic physics-based simulation process. Only this model -- and neither the alternatives relying exclusively on simpler representations (e.g., dynamic image features such as velocity coherence) nor alternatives based on deep learning approaches -- was able to explain observed behavioral patterns. These behavioral and computational results suggest the perception of soft materials is governed by a form of "intuitive physics" -- an abstract, physics-based representation of approximate cloth mechanics that explains observed shape variations in terms of how unobservable properties determine cloth reaction to external forces.

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Poster Session B > Visual Memory: Imagery, drawing, scenes > Poster B36

Seeing cloth-covered objects: A case study of intuitive physics in perception, attention, and memory

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We typically think of intuitive physics in terms of high-level cognition, but might aspects of physics also be extracted during lower-level visual processing? In short, might we not only *think* about physics, but also *see* it? We explored this in the context of *covered* objects -- as when you see a chair with a blanket draped over it. To successfully recover the underlying structure of such scenes (and determine which image components reflect the object itself), we must account for the physical interactions between cloth, gravity, and object -- which govern not only the way the cloth may wrinkle and fold on itself, but also the way it hangs across the object's edges and corners. We explored this using change detection: Observers saw two images of cloth-covered objects appear quickly one after the other, and simply had to detect whether the two raw images were identical. On "Same Object" trials, the superficial folds and creases of the cloth changed dramatically, but the underlying object was identical (as might happen if you threw a blanket onto a chair repeatedly). On "Different Object" trials, in contrast, both the cloth and the underlying covered object changed. Critically, "Same Object" trials always had *greater* visual change than "Different Object" trials -- in terms of both brute image metrics (e.g. the number of changed pixels) and higher-level features (as quantified by distance in vectorized feature-activation maps from relatively late layers in a convolutional neural network trained for object recognition [VGG16]). Observers were far better at detecting changes on "Different Object" trials, despite the lesser degree of overall visual change. Just as vision "discounts the illuminant" to recover the deeper property of reflectance in lightness perception, visual processing uses intuitive physics to "discount the cloth" in order to recover the deeper underlying structure of objects.

Acknowledgements: This project was funded by ONR MURI #N00014-16-1-2007 awarded to BJS.

Plasticity and Learning 1

Poster Session B > Plasticity and Learning 1 > Poster B41

Pairing a visual stimulus with VTA micro-stimulation changes the response properties of posterior inferior temporal cortical neurons

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Jerome Herpers[1], Wim Vanduffel[1,2], John Arsenault[1], Rufin Vogels[1]; [1]Leuven Brain Institute, KU Leuven, [2]Harvard Medical School

Training can increase the performance in visual detection and discrimination tasks, a phenomenon of adult plasticity known as visual perceptual learning (VPL). Neural correlates of adult VPL include changes in the selectivity of neurons in visual areas. It is hypothesized that this plasticity is gated by reward signals, even in the absence of attention to the stimuli. Thus, mere pairing of reward with a stimulus can be sufficient to increase the representation of the paired stimulus. Indeed, previous fMRI studies in macaques in which electrical micro-stimulation of the ventral tegmental area (VTA-EM) was paired with a weak visual stimulus showed increased activations in posterior inferior temporal (PIT) cortex for the VTA-EM-paired stimulus (Arsenault & Vanduffel, Nature Communications, 2019). Here, we examined changes in neural responses and selectivity by recording spiking activity in PIT after pairing a grating orientation with VTA-EM. Two monkeys performed an orthogonal color discrimination task, while a low visibility grating was paired with VTA-EM. After 15-20 VTA-EM sessions, daily VTA-EM was followed by multi-unit activity (MUA) recordings in PIT during a fixation task presenting high visibility gratings of different orientations and a color discrimination task presenting low visibility gratings. The experiment was repeated with VTA-EM pairing of the orientation perpendicular to the paired orientation of the initial experiment. We observed that the relative proportion of units with a preference for the VTA-EM-paired orientation increased compared to the orthogonal orientation. A relative increase in mean spike rate was observed for the VTA-EM-paired orientation, as well. Significant effects of pairing were present for response variability (Fano factor) and noise correlations, but inconsistent over subjects, suggesting that the response changes did not result from attentional modulation. In conclusion, pairing VTA-EM with a low visibility grating stimulus while performing an

orthogonal task induces changes in orientation preference of PIT neurons.

Acknowledgements: Funding: KU Leuven C14/17/109

Poster Session B > Plasticity and Learning 1 > Poster B42

Neural mechanisms underlying enhanced visual search performance in action video game players

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Individuals who play action video games have demonstrated faster response times on a range of cognitive tasks, but various changes across the chain of processing could contribute to the ultimate quickening in response. Some research has begun to identify neural markers associated with enhanced performance in gamers and has established that there are differences in low-level visual processing, attention allocation and visual working memory. However, gaming-related improvements could also arise from quicker preparation and execution of the motor response, and potential changes in the motor-related LRP have yet to be explored. Additionally, prior work has focused on changes in a limited number of early ERP components in isolation; therefore, further research is required to identify the relative contribution of each stage of processing to the observed behavioural changes. Using similar methodology as Clark et al. (2015), we tested action video-game players and non-video-game players and recorded EEG while participants performed a visual search 'popout' task. We assessed amplitudes and latencies of key ERP components, specifically, the N1 (early sensory processing), N2pc (attentional orienting to stimulus), CDA (target processing, discrimination, and manipulation of information in visual short-term memory), and both the stimulus-locked and response-locked LRPs (preparation for motor response). As expected, gamers demonstrated faster response times relative to non-gamers, and EEG analyses revealed the neural mechanisms underlying these behavioural differences. Improved performance in gamers was accompanied by changes across the processing chain from stimulus to response, evidenced by differences from the early sensory-evoked N1 component through to the later motor-related LRP component. Our findings suggest that enhanced visual search performance in action video game players is driven by differences in early sensory processing in combination with changes to later cognitive and motor processes.

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Poster Session B > Plasticity and Learning 1 > Poster B43

Skipping breakfast changes visual processing: incretins contribution to short-term visual plasticity

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INTRODUCTION. Metabolic dysregulation, e.g. obesity and diabetes, affects plasticity-dependent cognitive functions. Recent data indicate that sensory plasticity is similarly affected, and negatively correlated with BMI. So far, metabolic effects were studied in pathological conditions and/or in the long term. We asked whether metabolic factors also modulate plasticity continuously and physiologically, for example every time we have breakfast (or skip it). METHODS. In 11 adult volunteers, we indexed sensory plasticity by measuring binocular rivalry before and after 2 hours of monocular deprivation. We repeated measurements on three mornings: 1) after overnight fasting; 2) with a controlled meal; 3) with an infusion of glucagon-like-peptide-1 (GLP-1). GLP-1 is an incretin released with every meal; it triggers the insulin response that reduces blood glycemia (we counteracted the would-be-hypoglycemia with titrated glucose infusions). RESULTS. Monocular deprivation transiently shifted ocular dominance in favor of the deprived eye. This form of plasticity was systematically stronger upon meal consumption than after overnight fasting (paired t-test, $t = 2.407$, $p < 0.05$). Although the GLP-1 infusion did not mimic meal consumption, plasticity upon GLP-1 infusion was tightly correlated with GLP-1 blood concentrations (variable across participants and slightly higher than upon meal

consumption) and with an index of insulin sensitivity (HOMA-IR). Correlation coefficients were > 0.9 (p<0.001) even after factoring out the associations with infused glucose. CONCLUSIONS. Having breakfast enhances sensory plasticity as measured by short-term monocular deprivation, and sensory plasticity correlates with the incretins-insulin pathway activation achieved through GLP-1 infusion. The incretins-insulin pathway activation is one of the many (peripheral, autonomic and central) consequences of meal consumption, and our data suggest that GLP-1 is not the only mediator of its impact on neural dynamics. These findings strongly indicate that metabolic factors modulate neural dynamics even in low-level sensory cortex such as implicated in the monocular deprivation effect.

Poster Session B > Plasticity and Learning 1 > Poster B44

Sequence learning is surprisingly fragile in visual search

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Extensive research has shown that people are sensitive to statistical regularities of visual stimuli, such as a repeated sequence of target locations. To date, sequence learning of target locations has primarily been investigated in relatively simple scenarios involving a single object appearing in isolation. Many daily activities, however, require people to search for a target object from complex environments. To understand how repeated sequences of object locations are used in daily activities, we tested whether sequence learning also manifested in complex displays. Using variants of the serial reaction time (SRT) task, we asked participants to report the screen quadrant of a letter T, whose location followed a 12-trial sequence that repeated 30 times over 360 trials. Across different experiments, we manipulated the nature of distractors surrounding the target. The T could appear in isolation, as a color singleton among distractors with fixed or variable locations, or as a conjunction search target. Sequence learning, manifested as elevated response time when the learned sequence was disrupted, decreased in strength as spatial noise increased. Learning was robust when the T appeared in isolation or when it was surrounded by distractors that did not change locations across trials. It was reduced in a feature search task and eliminated in a conjunction search task. We further showed that after successful acquisition of sequence learning using unvarying distractors, changes in the distractor locations could disrupt sequence learning, even though the target sequence was maintained. This finding is consistent with the relational encoding account, suggesting that the target locations are coded in relation to concurrently presented distractors. Variability in distractor locations disrupts target sequence learning, revealing a limit in people’s ability to extract and use spatiotemporal regularities in complex visual environments.

Poster Session B > Plasticity and Learning 1 > Poster B45

Task-irrelevant perceptual learning of moving natural stimuli induces a bias away from the exposed movement direction

View Poster | Visit me in Gather.Town Manatee Room on Sunday 8:00 am - 10:00 am EDT

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Although visual research often employs artificial stimuli, real visual systems are highly tuned to the properties of naturalistic stimuli (Rao & Ballard, 1999). It has been found that task-irrelevant perceptual learning (TIPL) of suprathreshold stimuli does not occur because of inhibition to the stimuli (Tsushima, Sasaki & Watanabe, 2006). At the same time, it has been reported that no or less attention is necessary for a task-irrelevant naturalistic stimulus to be proceeded (Li et al., 2002). In the present study, we investigated if suprathreshold naturalistic stimuli can circumvent attentional inhibition in TIPL. Six subjects received ten sessions of exposure to moving natural scenes. In each trial (8000 total), subjects completed a central RSVP task while a surrounding natural image moved in a constant direction for each subject (direction randomized between subjects). Before and after exposure, subjects completed a dot motion discrimination task in which they were instructed to identify the direction of 5% or 10% coherently moving dots from among seven equidistant directions (560 trials). Accuracy in the RSVP task increased from 63% to 79% across sessions. Unlike other TIPL studies, motion discrimination accuracy for the exposed direction decreased by about 25%, while an increase of 5% was found for the other directions. Closer investigation revealed that this change was due to a change in response behavior. Given any veridical direction, responses toward the exposed direction decreased by 16%, but increased to the two directions most distant from it (±154°) by 17%. The two intermediate directions did not change noticeably on average (-2% for ±51° and +3% for ±103°). These results suggest a disruptive effect for the exposed direction on TIPL of the direction if the moving backgrounds are natural scenes or, alternatively, a facilitatory effect of the possible head motion direction (as opposed to the low-level pixel movement direction).

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Poster Session B > Plasticity and Learning 1 > Poster B46

Spatiotopic skew distortion adaptation with simultaneously present opposing stimuli

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Some optical elements, like corrective spectacle lenses with a progressive change in optical power, distort the visual field of the wearer. Optical distortions alter visual form and motion features, processed also up to higher areas of the visual system. Consequently, as has been shown, adaptation to distorted natural stimuli induces spatiotopic aftereffects: after a saccade subsequent to adaptation, aftereffects are present not only at the adapted retinal location, but also at the spatial location of adaptation stimulus. Because of the spatial variation of distortions in lenses, eye movements constantly modulate strength and orientation of the distortions present in the visual field. For progressive addition lenses, for example, left and right part of the lens skew distort the visual field in opposite directions. Switching gaze from one side to the other could stimulate adaptation with opposing retinotopic and spatiotopic aftereffects. For this study, 10 subjects were presented with two oppositely distorted adaptation stimuli simultaneously. To do so, a video with natural image content was skew distorted in opposite directions. Both distorted videos were shown simultaneously at distinct locations on the left and right side of a screen. Gaze was controlled by eye tracking and guided to repeatedly switch between the two stimuli during the 5 minutes of adaptation. Aftereffects of distortion adaptation were measured in a motion direction identification task. Before and after adaptation, the motion angle of a group of coherently moving dots perceived as horizontal was determined for both stimulus locations independently. A significant difference was found in the shift of perceived motion direction between the two stimulus locations. The direction agrees with the distortion direction shown during adaptation at the respective screen locations. Therefore, in case of prolonged adaptation with gaze switching between opposite skew distortions, retinotopic aftereffects of distortion adaptation are suppressed by the spatiotopic adaptation effects.

Poster Session B > Plasticity and Learning 1 > Poster B47

Recovering Spatial Structure in Spatio-Temporal Visual Statistical Learning

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While research on visual statistical learning (VSL) is divided into two distinct lines investigating the learning of temporal and spatial regularities separately, such a distinction does not hold in real-world environments, where the two types of regularities are perpetually intertwined as spatial patterns unfold over time. We investigated the interplay between spatial and temporal regularities in a new VSL paradigm, in which spatially defined chunks were continuously moving in and out of the observer's view. First, participants passively observed a stream of stimuli in a task-free setup. Scenes composed of novel shape-pairs (oriented horizontally, vertically, or diagonally) were presented through a 3x3 grid aperture without between-pair segmentation cues. Periodically, the whole scene within the aperture moved a grid to a direction so that some shapes moved out and others moved in the aperture, thus showing particular pairs only partially sometimes. Subsequently, participants completed a 2AFC familiarity-task judging between real and foil pairs. In Experiment 1 (n=20), participants showed the same level of correct responses in this new setup as in classical spatial VSL experiments (M=61.11%, SE=3.19, p=0.003, BF=16.31). In Experiment 2a (n=73) and 2b (n=75), we introduced different levels of spatial noise by biasing the ratio between specific movement directions. More horizontal movement led to significantly more partial presentations (i.e. more noise) of horizontal than vertical pairs, and vice versa. Despite strong differences in the spatial conditional probabilities within the different types of pairs due to these manipulations, learning of pairs was not selectively hindered, observers performed equally well with all pair types. Evidently, observers can rely on the high temporal coherence of the evolving scenes to recover and represent the spatial structure regardless of spatial noise, and their learning is not a direct consequence of exposure frequency.

Poster Session B > Plasticity and Learning 1 > Poster B48

Pupil dynamics signals visuo-spatial statistical learning

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Although statistical learning has been established as an important constituent of human implicit sensory learning capacities, the actual process of statistical learning rather than its outcome is largely unexplored due to the lack of appropriate measures. One candidate measure is changes in pupil diameter, which is known to be influenced by past experiences (e.g., violation of expectation, belief updating, pupil old/new effect), but has not been investigated in the more complex context of implicit statistical learning. We explored whether pupil dynamics of observers (N = 88) can be used as a continuous measure of statistical learning in a paradigm, where we manipulated the explicit knowledge of participants about the to-be-learned regularities of multi-element visual scenes. We introduced trials that violated the scene structure into the continuous stream of structured scenes presented during the learning phase. After an initial period of learning, pupil dilation was larger for these violation trials than for regular learning trials ($p < 0.01$). Importantly, during both explicit and implicit learning, the magnitude of pupil dilation for violation trials positively correlated with the amount of knowledge participants demonstrated at the subsequent test phase (r (explicit) = 0.44, $p < 0.05$; r (implicit) = 0.48, $p < 0.01$). We also found that observers with explicit prior knowledge about the underlying structure of the scenes demonstrated the emergence of these effects earlier during the learning phase compared to implicit learners without such knowledge. Our results demonstrate that pupil dilation can be used to track the accumulation of visual information, even in complex learning scenarios, irrespective of the explicitness of task instructions. Combined with research on eye-movements, our findings can be used for developing novel, active teaching-based experimental paradigms, in which the learning state is continuously assessed, and subsequent stimuli are selected accordingly for improved learning performance.

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Mutual information predicts the magnitude of categorical perception in a shape space

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Categorical perception, or more precisely the associated phenomenon known as "acquired distinctiveness" (AD), refers to the enhancement of perceptual sensitivity along category-relevant or "informative" perceptual features as a result of category training. But exactly which perceptual features the system treats as "informative" is not well understood, in part because almost all studies to date have used categories separated by a hard boundary, in which only one feature---the one crossing the boundary---is informative by any reasonable definition. This study aims to investigate more comprehensively which perceptual features enjoy an improvement in perceptual sensitivity as result of category training. In a series of experiments, subjects learned to distinguish two shape categories defined as Gaussian distributions in an unfamiliar 2-dimensional feature space. These categories define a "soft" optimal linear boundary, whose precision could be controlled by modulating the category overlap. Shape features that are orthogonal to this boundary are maximally informative about category membership; features that are parallel to the boundary are completely uninformative; and other features (e.g. "diagonal" features) have intermediate levels of informativeness. The degree of informativeness of each feature can be defined as the mutual information between the feature and the category variable, which is the degree to which knowledge of the feature reduces Shannon uncertainty about the category. Perceptual discrimination was tested before and after category learning at various features in the space, allowing the magnitude of AD attributable

to training to be measured. The results support a remarkably simple generalization: the magnitude of improvement in perceptual discrimination (AD) at each feature was proportional to the mutual information between the feature and the category variable. This finding suggests a "rational" basis for categorical perception, in which the precision of perceptual discrimination is tuned to the statistical structure of the environment.

Acknowledgements: NIH (NEI) R01 021494

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Replicating Synesthetic Stroop effects in Non-synesthetic Contexts

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Synesthesia Stroop has been used as a method to attest genuine synesthetic grapheme-color associations, relying on automatic/interference processes similar to the original Stroop (1935) effect. Graphemes presented in colors either congruent or incongruent to participants' synesthesia result in a Stroop-like effect. In an "ink naming" task, participants have to name the ink color displayed, whereas in a "retrieval" task, participants have to name their synesthetic color-associations. Here we investigate the robustness of the Synesthesia Stroop results. We hypothesized that for semantic associations (e.g., B is Blue), the congruency effect relies on the traditional Stroop mechanism (i.e., the initial letter triggering the automatic color name). We also investigated whether the memory retrieval processes can generate the congruency effect, rather than interference from automatized color associations. Eighteen synesthetes and 18 non-synesthetes completed four different variations of the ink naming and retrieval Stroop/Synesthesia Stroop. Exp 1 was a traditional Stroop experiment, in Exp 2 participants were presented only the initial letter of color words. Exp 3 was the usual Synesthesia Stroop experiment (performed on synesthetes only) and in Exp 4 we performed a Trained Synesthesia Stroop on both groups which was preceded by a 3-minute exposure to novel grapheme-color associations. Our results demonstrate that the usual Stroop and the Initial Stroop yield identical results in both groups (Exp 1 & 2). Second, results from the Synesthesia Stroop task was replicated in the Trained Synesthesia Stroop, for both groups (Exp 3 & 4) during the retrieval task, however, not in the ink naming task. Thus, we show that Synesthesia Stroop on semantic associations seem confounded by the traditional Stroop effect or semantic priming. We also reveal that the Synesthesia Stroop retrieval task may in fact not measure automatic synesthetic processes but rather memory retrieval whereby an ink-naming task appears a more reliable measure.

Acknowledgements: Sino-Danish Center for Education and Research

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Failure to account for extrinsic noise when integrating visual cues and prior information

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Information integration for perception and decision making can be near-optimal, such as reliability-weighted averaging of sensory cues (Ernst and Banks, 2002) or sensory cues and prior knowledge (Wolpert et al. 2011). Behaviour diverges from optimal in a variety of circumstances (Rahnev and Denison, 2018). Recent studies suggest suboptimalities arise as perceptual and decision-making systems are not equally sensitive to all sources of uncertainty. Castanon et al. (2018) suggest un-certainty brought about through sensory encoding noise can be accounted for, but uncertainty in higher level integration processes cannot. Similarly, Kiryakova et al. (2020) hypothesise that uncer-tainty arising within perceptual/decision-making systems (intrinsic noise) can be tracked, but un-certainty arising in the world (extrinsic noise) cannot. Here, 40 participants used intrinsic-only or intrinsic+extrinsic noise visual cues (dot-clouds) and prior information (Gaussian base-rate distribu-tions shown and reinforced through feedback) to estimate the location of a hidden target. Intrin-sic-only cues were four dots from a Gaussian centred on the true location with low/high variability (low/high intrinsic noise). Intrinsic+extrinsic cues were centred on a position varying about the true location according to a draw

from a second Gaussian, adding extrinsic uncertainty. Participants bi-ased their responses more towards the prior when presented with high compared to low intrinsic noise cues ($p < .001$) but did not adjust the weight given to the cues when extrinsic noise was add-ed ($p = .209$). Accordingly, the weight placed on the cue was further from optimal when extrinsic noise was present ($p < .001$). Subjective uncertainty measures suggest participants were not fully aware of the extent of the added extrinsic noise. These results are in favour of the hypothesis that perceptual and decision-making systems struggle to track and account for extrinsic noise. They suggest optimal information integration for perception and decision-making is only possible when accounting for specific types of uncertainty.

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Common structure underlying visual and non-visual judgments of randomness

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If you flip a coin and receive 10 'tails' in a row, that outcome is surprising; you may even question whether that outcome was truly random. Much work has addressed how we reason about randomness in cases like these. Yet randomness is not just something we think about; it is also something we see. Imagine a bookcase with books sorted by color, or size; you would quickly, effortlessly perceive the non-randomness of the display. But to what extent are these two processes (thinking about vs. seeing randomness) related? That is, do visual impressions of randomness and judgments of randomness share any underlying structure? We presented participants with 10x10 grids, wherein each cell was one of two colors. Each grid was generated with a transition probability (.1, .3, .5, .7, .9), or the likelihood that each cell in the grid was the same as the previous one (moving left to right, top to bottom). They were simply asked to indicate whether the displays were random or non-random. Unbeknownst to participants, each unique stimulus was shown 4 times, each with a different viewing duration (250ms, 500ms, 1000ms, unlimited time). Our critical question is the extent to which participants agree with themselves across durations. In fact, we find relatively high consistency (>70% agreement across the shortest and longest durations), indicating that impressions of randomness at short durations are highly similar to judgments of randomness at longer durations. Further, responses in this visual task (at all durations) are highly correlated with responses in a matched, non-visual task (in which participants assessed the randomness of series of coin flips). These results suggest that seeing and thinking about randomness may rely on some of the same underlying statistical processes.

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From fixation to fixational eye movements – microsaccades in perceptual learning

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[Goal] Visual perceptual learning (VPL) refers to improvements in sensory discrimination due to repetitive practice. VPL has been extensively studied at peripheral locations, while observers fixate at the center. Microsaccades are fixational eye movements with amplitudes ≤1 degree. The role of microsaccades has been established in a variety of perceptual tasks, but it is unknown whether and how microsaccades change along with human perceptual learning. Here we investigated whether and how microsaccade rates vary during and after VPL when observers trained under feature-based attention (FBA) or a neutral condition. [Methods] Observers performed an orientation discrimination task. Each trial began with a fixation period followed by a cue. After an ISI, a Gabor stimulus was presented for 200ms, followed by a response window. Five offsets were used to assess different difficulty levels. Twenty observers participated in a six-day VPL study: 10 in a neutral condition and 10 in a FBA condition. Eye fixation was monitored by an eye-tracker. Microsaccades were extracted with a standard velocity-based detection algorithm. VPL was re-assessed after ~3.5 and ~12 months. [Results] Performance improved at the trained location with the trained feature for both groups, and learning transferred to an untrained location for the attention group. Both groups showed a typical pattern: microsaccades were largely suppressed during the stimulus presentation, followed by a rebound during the response window, regardless of task difficulty. The rebound of microsaccade rates was greatly reduced after VPL, and this reduction gradually emerged during training. This pattern remained after ~3.5 months for both groups and remained after 1 year only for the Attention group. [Conclusion] This study reveals that the rates of microsaccades change after perceptual learning, and that such a change is long lasting, and more so when observers trained with FBA.

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Visual field defects – correspondence of fMRI and subjective estimates

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Recent advances in vision restoration techniques make it critical to objectively probe visual field (VF) defects, not only at the retinal but also at the cortical level. Here we assessed the potential of objective fMRI-based VF tests. To compare several fMRI-based VF-mapping approaches, we performed fMRI-based pRF-mapping (visual-field radius: 14°; 3T) in six patients with extensive VF-defects (4 glaucoma (GL); 2 retinitis pigmentosa (RP)) and six healthy controls (HC) with simulated peripheral scotoma (>7°). VF-coverage in V1 was reconstructed from (i) pRF-estimates[1], (ii) an anatomical retinotopic template[2], (iii) a Bayesian-inference approach[3] and compared to standard-automated perimetry (SAP) results. To assess the stimulus/task dependence, we also reconstructed VFs from fMRI data with block-design stimulation [drifting contrast patterns (8-directions) ON (12 s)/ OFF (12 s)] with different visual tasks, (i) passive viewing (PV) or (ii) a one-back task (OBT), i.e. reports of successions of identical motion directions. For the conventional-pRF-modeling approach, we found a stronger correspondence with SAP estimates in the controls [r=0.81 (median)] than in patients (r=0.57). The task-fMRI correlations were smaller than the pRF-mapping correlations, but followed a similar trend with the correspondence of patients' falling short than controls. The differential correspondence for PV vs. OBT (r=0.29 vs. r=0.16) in patients, but not in controls (r=0.67 vs. r=0.65), indicated task-dependent dynamics in the VF-predictions in patients with VF-defects. The anatomy-based and Bayesian-based modeling approaches had better SAP-correspondence than the pRF approach in the patient group (PV: r=0.44 vs. r=0.42 vs. r=0.29; OBT: r=0.36 vs. r=0.32 vs. r=0.16). Our study demonstrates the feasibility fMRI-based VF-reconstructions, but also highlights the current limitations of translating fMRI-based methods to a clinical work-up. References: [1] Dumoulin & Wandell, 2008. https://doi.org/10.1016/j.neuroimage.2007.09.034 [2] Benson et al., 2014. https://doi.org/10.1371/journal.pcbi.1003538 [3] Benson & Winawer. 2018. https://doi.org/10.7554/eLife.40224

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Chiasmal malformations dataset: a unique neuroimaging testbed

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The human optic chiasm is formed normally by almost equal populations of crossing and non-crossing optic nerve fibers. This proportion can be affected by rare disorders, such as albinism or achiasma (Hoffmann and Dumoulin, 2015), causing, respectively, over- or under-representation of crossing fibers. In the light of recent studies revealing those differences from anatomical measures (Puzniak et al., 2019), the optic chiasm appears as a valuable model for researchers interested in the impacts of deficits of vision on brain white matter or tractography methods developments. In order to provide the research community with an access to this unique model, we make the MRI dataset, thoroughly describing chiasmal malformations, available. We recruited patients with albinism (n=9), achiasma (n=2), and matching controls (n=8). For the patients we collected ophthalmological records including visual acuity, fixation stability estimates and results of visually evoked potentials measurements. Further, we collected high quality structural and diffusion brain MRI data of all participants. In addition, in a subset of participants with albinism (n=6) we acquired retinotopic maps using functional MRI (Ahmadi et al., 2019). The MRI data was clinically examined, technically validated, preprocessed using state-of-the-art pipeline and made publicly available on the brainlife.io platform (Avesani et al., 2019). This includes structural, diffusion and functional MRI data (both raw and preprocessed versions) and their derivatives (such as manually curated white matter masks). Through sharing a MRI dataset on chiasmal malformations, the wide research community can incorporate this unique condition in their research approach.

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Broad and long-lasting vision improvements in youth with infantile nystagmus after home training with a perceptual learning app

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Current treatments for infantile nystagmus (IN), focused on dampening the oscillating eye movements, yield little to no improvement in visual functioning. It makes sense, however, to treat the visual impairments associated with IN with tailored sensorimotor training. Recently, we therefore developed a letter discrimination training embedded in an eye movement task. This training improved visual performance of children with IN, but most children had not reached plateau performance after 10 training sessions (3,500 trials). Here, we test the effects of prolonged visual perceptual learning (14,000 trials) in 7-18-year-old children with IN, targeting visual crowding as an important bottleneck in their visual functioning. Children (n=36) were assessed before and after training and we performed follow up measurements after 6 months. The training program not only improved performance on the trained letter-discrimination tasks (uncrowded and crowded acuity improvement 0.08±0.03 logMAR and 0.19±0.05 logMAR, respectively; reduction crowding extent 0.31±0.05 logMAR). It also improved visual acuities measured with clinical vision charts at distance (5m, uncrowded 0.15±0.02 logMAR; crowded 0.18±0.02 logMAR) and at near (40cm, uncrowded 0.09±0.02 logMAR, crowded 0.10 ± 0.02 logMAR). We also observed transfer of training effects to untrained tasks such as reading (improvements in reading acuity and reading speed 0.07±0.02 logMAR and 16±2 wpm respectively) and even stereopsis (improvement of 0.22 ± 0.06 log10arcsec). In addition, we found that the training effects translated into improvements of daily-life functioning (as assessed with a functional vision questionnaire), and that they were long lasting (no significant decline after 6 months). The transfer to untrained conditions did not result from improved contrast sensitivity. We conclude that training with an engaging perceptual learning app at home elicits broad and long-lasting vision improvements in youth with IN. Improvements on self-reported functional vision scores underline the clinical relevance of perceptual learning with e-health apps for individuals with IN.

Acknowledgements: This research was supported by ZonMw program InSight (grant number 94312005).

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Mechanisms that stabilize visual perceptual learning differ in children and adults: Evidence from psychophysics and magnetic resonance spectroscopy

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Visual perceptual learning (VPL) is defined as a long-term performance change on a visual task resulting from visual experience or training. After such training ends, VPL is fragile and needs to be stabilized against being retrogradely interfered with by new stimuli or tasks. Although stabilization is a well-established mechanism in VPL and other types of learning, it is unclear whether it changes across the life span. Here, we investigated how mechanisms that stabilize VPL change from childhood to adulthood. Participants (n = 13 children, 8-11 years old, and n = 14 adults, 18-29 years old) were trained on a two-interval forced choice orientation detection task with two different orientations in separate blocks. Between blocks participants rested for 60 min. VPL was measured as an improvement in detection performance for each trained orientation on a separate day. The results show that adults developed VPL only for the second trained orientation, indicating that VPL of the second trained orientation retrogradely interfered with stabilization of VPL of the first trained orientation. In contrast, children developed VPL for both trained orientations and did not show any interference, suggesting that post-training processing of VPL is significantly different between children and adults. We measured neurochemical mechanisms underlying the observed changes using magnetic resonance spectroscopy with new groups of participants (n = 13 children, 8-11 years old, n = 14 adults, 18-30 years old). We found that children after VPL training immediately exhibited increased concentrations of inhibitory neurotransmitter (GABA) over excitatory neurotransmitter (glutamate/glutamine) in visual cortex, whereas no such changes occurred in adults. These results suggest that children's VPL is stabilized against interfering stimuli or tasks by inhibiting interfering mechanisms in visual cortex immediately after training ends. These dynamics do not occur in adulthood, which makes VPL in adults more susceptible to retrograde interference.

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Perceptual learning with complex objects: A comparison between full-practice training and memory reactivation

View Poster | Visit me in Gather.Town Manatee Room on Sunday 8:00 am - 10:00 am EDT

Chiu-Yueh Chen[1], Hans Op de Beeck[1]; [1]KU Leuven

Perception improves with repeated exposure. Evidence has shown object recognition can be improved by training for multiple days in adults. In particular, a study of Amar-Halpert et al. (2017) has compared the learning effect of repetitive and brief, at-threshold training on a discrimination task and reported similar improvement in both groups. The finding is interpreted as evidence that memory reactivation benefits discrimination learning. This raises the question how this process might influence different perceptual tasks, including tasks with more complex visual stimuli. Here, this preregistered study investigates whether reactivation induces improvements in a visual object learning task that includes more complex visual stimuli. Participants were trained to recognize a set of backward-masked objects during five days of training. After the initial training, a group was trained with repeated practice, the other with brief, near-threshold reactivation trials. In both groups we found improved object recognition at brief exposure durations. Traditional intense training shows a daily improvement; however, the group with reactivation does not reach the same level of improvement. Our findings suggest that perceptual learning with objects requires large amounts of practice.

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Attention: Objects

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Tracking moving objects with attention and working memory

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In everyday tracking, objects often temporarily disappear from observer's view to reappear later. For instance, while driving on a busy road some cars may slip into your blind spots. In order to drive safely, you need to maintain an approximate location of the hidden cars in your memory although you cannot track them visually for a moment.

Consequently, everyday tracking seems to require both working memory and attention. In presented experiments, we measured performance in Multiple Object Tracking in a circular arena and manipulated the visible area with an aperture. During the trial, one or more objects could temporarily disappear behind the visible edge of the arena. First, we compared a condition with no cover with three situations with increasing amount of cover (17%, 33%, 47%). Participants (N=50) were asked to track 4 of 8 objects for 8 seconds. Mean accuracy was associated with amount of cover and ranged from 72% to 90%. The logistic model showed that even the situation with the smallest cover, where objects could not fully disappear, impaired the ability to track a target (odds ratio 0.76). In the second experiment (N=47), we tested whether lower tracking workload will help participants to better track objects beyond the visible border. We manipulated the amount of cover (17%, 33% and 47%) and number of tracked objects (2, 3 or 4). In all cover conditions the effect of lower workload was present but smaller relative to the effect of cover. Participants benefited more from the lower workload in situations of smaller cover (17% cover: OR 1.53 for each target less; 33% cover: OR 1.28; 47% cover: 1.08). Although people can track about four objects with their attention, the need to rely on working memory makes tracking substantially more demanding and the objects disappearing beyond borders are difficult to track.

Acknowledgements: The research has been supported by Czech Science Foundation (GA19-07690S)

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Visual sensitivity and reaction time measures show no evidence for purely exogenous object-based attention

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Most of studies of object-based attention use the classic two-rectangle paradigm (Egly et al., 1994) featuring a hybrid cue in which both exogenous and endogenous components draw attention to a location within an object. Response times in a simple detection task indicate the spread of covert attention along this object. Here, we tested whether (1) purely exogenous cueing evokes this object-based advantage; (2) this effect is also reflected in visual sensitivity. We measured sensitivity and response time in a visual discrimination task: Observers reported the tilt of an oriented noise patch (probe) briefly presented at the end of one of two rectangles, each filled with dynamic noise. At one of three time points before the probe, we flashed a cue at the end of one rectangle. This exogenous cue was 100% task-irrelevant, as the probe appeared either within the cued or the uncued object, but never at the cued location. By varying the contrast of the dynamic noise, we measured performance in five different signal-to-noise ratio (SNR) conditions. We expected a within-object benefit in response times for high SNRs, and in visual sensitivity for lower SNRs. Each participant completed four sessions of the experiment with response time prioritized over accuracy, followed by four sessions with accuracy prioritized over response time. Increasing SNRs substantially reduced response time and increased visual sensitivity. Moreover, for lower SNRs, responses were much slower for shorter cue-probe delays while sensitivity was unaffected. This effect suggests that our manipulation of SNR indeed affected the time required to extract visual information. Importantly, we did not find an object-based benefit in response time or sensitivity: Performance for probes presented in the exogenously cued vs. uncued objects was strikingly similar. Given the high power of our study, this finding suggests that object-based selection requires that cueing has an endogenous component.

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Excess success in studies of object-based attention

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Many subareas of psychology face a replication crisis; perhaps because past empirical research used inappropriate sampling, analysis, or reporting methods. These questionable research practices impeded scientific progress by

misleading researchers about effects and hindering theory development. To date, vision science was rarely mentioned in this context, but we show that many investigations of object-based attention seem to have similar problems. We applied the Test for Excess Success (TES) to each of 37 identified articles related to object-based attention with four or more experiments. Using the reported statistics and sample sizes, the TES estimates the probability that a replication of the studies in an article would produce the same degree of success as the original set of studies. For 19 of the articles (51%) this replication probability fell below 0.1, meaning that if the effects are real and of a similar magnitude as reported, it is unlikely that similar studies, with the same sample sizes, would reproduce the original results. Non-replicable results should not be trusted, so many of the articles do not provide adequate support for their conclusions. New studies will be required to properly examine the effects, and such studies will require much larger sample sizes or better designs. To investigate object-based attention with the classic two-rectangles paradigm, we ran an online study (n=274, estimated power of 0.97) and found a significant 14 millisecond reaction time advantage when a cue and target appear in a common rectangle compared to when they appear in different rectangles. Based on this finding, we suggest that studies of object-based attention require sample sizes nearly ten times larger than what are commonly used.

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Have a look - the role of covert attention shifts for object integration: Evidence from pupillometry.

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The present study investigated whether the integration of separate parts into a whole-object representation requires attention to be allocated at the location of an object. To this end, two experiments were performed, which required observers to maintain central fixation while searching for a target configuration in peripheral vision among various distractor configurations. The target could either be a “grouped” whole-object Kanizsa figure, or an “ungrouped” configuration of identical figural parts, but which do not support object completion processes to the same extent. In the experiments, accuracies and changes in pupil size were assessed, with the latter reflecting a marker of the covert allocation of attention in the periphery. The results in Experiment 1 revealed a performance benefit for grouped (relative to ungrouped) targets, which increased with decreasing distance from fixation. Moreover measures of pupillary dilation mirrored this eccentricity-dependent advantage for the localization of grouped targets. Next, to further probe the coupling between attention and grouping, in Experiment 2, an additional attention-demanding central task was introduced. This additional task hampered performance overall, alongside with corresponding pupil size changes, thus showing that attention was bound to the central task. However, there was still a substantial benefit for grouped over ungrouped targets in both the behavioral and the pupillometric data. This suggests that initial perceptual grouping operates independently from the allocation of covert attention, but pupil size changes also appear to reflect the subsequent (attention-dependent) comparison of a grouped target with a corresponding target template.

Attention: Inattention and lapses

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Lapses in sustained attention predicted by changes in visually-guided movements

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Previous research has linked keypress response times (RTs) to gradual shifts in sustained attention. Specifically, RTs are typically shorter and/or more variable prior to commission errors on no-go trials in the gradual-onset continuous performance task (Rosenberg et al., 2013), indicating a link between keypress response latency and fluctuations in sustained attention over time. We expanded on this research in a novel task where we asked participants to make repetitive visually-guided movements. Participants were required to reach out and press a display every time a continuously moving ball collided with a stationary box and to withhold their response every time the ball narrowly missed the box. The latter no-go trials occurred only 10% of the time, so participants were frequently reaching to the

target. We measured data from both hand and eye movements. We found that movement initiation latency (but not movement time) was shorter preceding commission errors on no-go trials relative to trials where the participant correctly withheld their response (correct rejections). This measure proved quite sensitive, with significant differences observed even when only examining the single trial that preceded the no-go trial. In other words, when participants initiate their movements quickly, they are more likely to make subsequent errors that indicate lapses of sustained attention. Pupil size was correlated at the subject level with initiation latency, but did not predict commission errors. Together these data suggest that studying complex behavior may be valuable in uncovering sensitive measures that indicate when a person is losing focus during a sustained attention task. Further, by isolating specific components of motor output, we may be able to link drifts in sustained attention to specific sub-processes of attention and cognitive control (e.g., Erb et al., 2016).

Acknowledgements: This work was funded by NIH 1R15NS113135-01

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What we've been missing about what we've been missing: Above-chance sensitivity to inattentional blindness stimuli

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Inattentional blindness—the failure to report clearly visible stimuli when attention is otherwise engaged—is among the most striking and well-known phenomena in psychology. But does inattention really render subjects "blind," or do they see more than their reports suggest? Standardly, IB studies simply ask subjects whether they noticed anything unusual on the critical trial, treating anyone who says "no" as having failed to perceive the stimulus. Yet this yes/no measure is susceptible to bias. Subjects might respond "no" because they were under-confident whether they saw anything (or whether what they saw counted as unusual), because they doubted that they could identify it, etc. Here, we address this problem by modifying the classic IB paradigm to allow derivation of signal-detection measures of sensitivity and bias. Subjects' primary task was to report which arm of a briefly presented cross was longer. In Experiments 1 and 2, the last trial included an unexpected stimulus. However, after the traditional yes/no question, subjects also answered a two-alternative forced-choice (2AFC) question, e.g., "Was the stimulus on the left or right?" or a forced-response question, e.g., "Was the stimulus red or blue?". We found that subjects who reported not noticing the IB stimulus could nevertheless discriminate its features (e.g., color, location) well above-chance. In Experiment 3, only two-thirds of subjects were shown an unusual stimulus, providing a false-alarm rate with which to derive detection-theoretic statistics. Subjects also provided confidence ratings for their reports, allowing us to construct confidence-based ROC curves. As predicted, yes/no reports were conservatively biased (i.e., subjects tended to say "no"). Sensitivity did not differ significantly across yes/no and 2AFC tasks, suggesting that standard estimates of IB may be inflated by such biases. These results are consistent with a rarely discussed account of IB: Inattention does not abolish awareness; rather, it degrades it.

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Attention Differentially Modulates Brief and Prolonged Inhibitions in Paracontrast Masking

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Visual masking is a powerful methodological tool to control object visibility at different stages of sensory processing. An important question to ask is how attention modulates identified distinct processes and thus alters the perceived visibility of a target. Particularly, paracontrast masking paradigms provide an important framework to shed light on this basic question. Previous studies indicated that distinct processes are involved in paracontrast masking (Breitmeyer et al., 2006). For example, brief and prolonged inhibitions have been observed at short and long stimulus onset asynchronies (SOAs), respectively. They have been interpreted as reflecting low- and high-level inhibitory (i.e., lateral vs. recurrent) mechanisms in the parvo-dominated pathway associated with perceived visibility. In the current study, we specifically aimed to understand how spatial attention alters these inhibitory mechanisms. Similar to previous research on metacontrast masking (Agaoglu et al., 2016), we manipulated spatial attention by changing set-size in the visual field. We employed a contour discrimination task on the visual target under different set-size and SOA conditions. A two-way repeated-measures ANOVA on the normalized performance values revealed a significant main effect of SOA and a two-way interaction between SOA and set-size. To elucidate the source of two-way interaction, we performed additional post-hoc comparisons across set-sizes. A significant effect of set-size was present at both short and long SOAs over which the brief and prolonged inhibitions were observed, respectively. Interestingly, these attentional modulations were in the opposite direction such that an increase in set size decreased the brief inhibition while increasing the prolonged inhibition. To conclude, these results indicate that spatial attention can take place at both low- and high-level visual processing. More specifically, they point to the differential effects of attention on the inhibitory mechanisms involved in controlling stimulus visibility at different processing stages.

Acknowledgements: Supported by The Scientific and Technological Research Council of Turkey (TUBITAK Grant 119K368)

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Expected and unexpected distractors in the Eriksen flanker task

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Expectations based on previous experience shape our perception by modulating attention. The effect of expectations on selective attention has been well-studied with regards to task-relevant stimuli, but less is known about the role that expectations play in suppressing task-irrelevant, distracting stimuli. We investigated the effects of distractor expectations using three experiments, all of which were based on a modified version of the classic Eriksen flanker task. We manipulated the frequency of specific flanker configurations, producing Standard and Oddball flankers. Experiment 1 tested how block-level flanker configuration probabilities (Standard/Oddball: 0.95/0.05, 0.90/0.10, 0.75/0.25, 0.50/0.50) affected accuracy and response time. Experiments 2 and 3 tested the interaction between "runs" of successive trials (length: 2, 4, 7, 11, 16) and block-level flanker configuration probability (Standard/Oddball: 0.90/0.10, 0.50/0.50) to better understand the dynamics of expectation, attention, and task performance. Across all studies, we found robust evidence for sensitivity to the probability of flankers, with an approximately logarithmic relationship between the likelihood of a particular flanker configuration and the accuracy of subjects' responses. The magnitude of this effect was larger for visually similar chevron stimuli, than for visually dissimilar letter stimuli. Subjects were sensitive to length of runs of repeated targets, but minimally sensitive to length of runs of repeated flankers. Our results demonstrate that the presence of statistical regularities across multiple time-scales and stimulus characteristics can affect performance. This is most likely accounted for by expectation-mediated distractor inhibition and from attentional capture resulting from its disruption. As a whole, these results show that expectations strongly influence attention in complex cognitive settings via multiple, nested factors.

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Meta-cognitive judgements of change detection predict change blindness

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In general, people tend to think that they will notice large changes made to visual scenes (Levin et al., 2000) and this collective overconfidence is part of what makes the phenomenon of change blindness so surprising. Yet, despite their overconfidence, are individuals in fact aware of and able to assess the relative difficulty of changes? We investigated whether participants' judgments of their ability to detect changes predicted their own change blindness duration. First, participants (N = 219) recruited from Amazon Mechanical Turk completed a standard change blindness task consisting of 30 scenes that cycled between an unmodified and modified version of the image. Participants pressed a button when they noticed the change, providing a measure of change blindness. After 6 to 7 months had passed, we re-contacted the same participants and showed them the same 30 scenes, now with the unmodified and modified versions presented side-by-side and a bounding box highlighting the change. Participants rated how likely they would be to spot the change

using a 5-point Likert scale. We found that participants' ratings of change detection significantly predicted their change blindness duration for each image, such that changes rated as likely to be spotted were detected faster than changes rated as unlikely to be spotted ($p < .001$). These ratings continued to be predictive when accounting for the eccentricity and size of the change ($p < .001$). However, there was no advantage to using participants' own ratings of change detection ability compared to the ratings from an independent group to predict change blindness duration, suggesting that differences among images (rather among individuals) contribute the most to change blindness. Together, these findings indicate that instead of having indiscriminate overconfidence, people are aware of the relative difficulty of changes and their meta-cognitive judgements of change detection ability accurately predict change blindness.

Acknowledgements: Wisconsin Alumni Research Foundation (WARF) and the UW–Madison Office of the Vice Chancellor for Research and Graduate Education

The role of emotional information in banner blindness

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The phenomenon of banner blindness is the ignorance of advertising banners and interface objects similar to them. Benway found that about 80% of users do not notice banner ads on websites (Benway, 1998). Several possible mechanisms are considered for the banner blindness occurrence. The type of information, user experience and attention inertia affect the distribution of attention and therefore banner blindness. Our study examined the effect of emotional valency and arousal on banner memorization and recognition. Participants' task was to search for a special link on an unfamiliar website. Images from the OASIS database were used as the banners (Kurdi et.al., 2016). They were selected based on their valency and arousal. There were 3 levels of valency (positive, negative and neutral) and 2 levels of arousal (high and low). Participants were asked to find the necessary link on the website as soon as possible. Participants were not informed about the presence of banners on the website. After participants completed the task, the link they found transferred them to a questionnaire, which included the questions about the presence and the contents of banners and a recognition task. Multinomial logistic regression tested the effects of emotional valency and arousal on banner recognition and memorization. Valency had a significant effect on banner recognition, but not on banner memorization. No main effect of arousal was found for banner memorization and recognition. Participants recognized banners with neutral valency better than negative and positive ones. Banners with negative valency were recognized worse than positive. We assumed that user experience had an influence on banner blindness. Previous experience helped users to understand that emotionally images in certain parts of the website usually carry useless information. It can also be concluded that both physical and affective features of the images influence the occurrence of the banner blindness.

Acknowledgements: Funding: The study was implemented in the framework of the Basic Research Program at the National Research University Higher School of Economics (HSE University) in 2021

Exploring the consistency of the affective consequences of cognitive-control for visual stimuli across tasks and individuals.

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Mechanisms of visual selective attention and motor-response control have affective consequences for associated stimuli. For example, images that are ignored or from which a response is withheld subsequently receive more negative affective ratings than the targets of attention/response. Although such effects have been observed in a variety of cognitive-behavioural paradigms (e.g., visual search, visual-memory search, Go/No-go, Think/No-Think, task-switching), leading accounts posit that the difference in stimulus ratings across experimental conditions is due to the effects of just one or two mechanisms that operate to either enhance or suppress visual stimulus/response representations (and thereby enhance or depress affective ratings) in each of these tasks. This suggests that there should be a reliable

correspondence in the difference between ratings of stimuli from conditions involving active attending/responding and those involving ignoring/response-avoidance across alternate visual tasks. To test this, we asked participants to complete in a single session the two different tasks most commonly used to assess the affective consequences of cognitive control—visual search and Go/No-go. Visual 'monster' cartoons that were ignored (search distractors) or from which a response had been withheld (No-go items) were rated more negatively than those that were the focus of attention (search targets) or response (Go-items). And there was a significant (albeit modest) correlation between the magnitude of the target vs. distractor rating difference and the Go vs. No-go rating difference obtained in the different tasks. Our investigation also examined the extent to which these visually-evoked affective responses are linked to common cognitive-control mechanisms or other distinct factors by including a series of cognitive and affective individual-difference measures. Taken together, our results are consistent with the view that affective ratings of visual stimuli are determined primarily by the influences of one or two cognitive-control mechanisms that remain consistent across task-types, but may also be influenced by additional cognitive and affective factors that may be unique to specific tasks.

Acknowledgements: Acknowledgements: Research funded by The Natural Sciences and Engineering Research Council of Canada (NSERC)

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Statistical regularity affects inattentional blindness

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Does statistical regularity affect inattentional blindness for natural scenes? Here we presented participants with statistically regular (i.e. good exemplars of four scene categories) or statistically irregular photos (i.e. bad exemplars or inverted good exemplars). We adapted Cohen et al.'s (2011) inattentional blindness paradigm and asked participants to perform an attentionally demanding RSVP task. Their task was to count the number of times a digit was presented in a stream of letters placed against a colorful checkboard background. Every 150 ms, the background changed, and with each change, a new digit or letter was presented. On the fifth (critical) trial, a scene image unexpectedly appeared behind the letter task, replacing the second-to-last checkerboard. Participants were asked if they noticed anything different on that trial and to describe the scene if they saw it. They were then asked to choose which of four scene photos was presented. Subsequently, participants completed three control trials that were similar to the critical trial except participants were told to ignore the letters and digits and only pay attention to the background. On the critical trial, 50% of the participants who received upright good exemplars experienced inattentional blindness, whereas 67% and 86% of the participants experienced inattentional blindness when the scene was a bad exemplar or inverted, respectively. Participants were also more accurate in choosing which photo appeared when the photo was a good exemplar. On the control trials, participants accurately selected the presented images on 94% of trials when the scenes were upright, whereas 75% and 78% of the bad exemplars and inverted images were accurately selected. Thus, participants were less likely to experience inattentional blindness for statistically regular scenes and were better at recognizing an image as having been presented in control trials when it was statistically regular (e.g. good exemplars) as opposed to irregular.

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The Attentional Blink when viewing Natural vs. Urban Scenes

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The current study aimed to identify how the allocation of attention when viewing natural vs. urban scenes impacts the attentional blink. Previous research has found that natural scenes produce a broader allocation of attention, allowing attention to spread across an image and potentially use less cognitive resources. Urban scenes, on the other hand, produce a narrowed allocation of attention, potentially allowing more efficient encoding of relevant information and inhibition of irrelevant information. Participants in Experiment 1 viewed a rapid serial visual presentation (RSVP) of 16 images from either a natural or urban scene category, where two target scenes were in color and the rest of the scenes were in greyscale. An attentional blink was evident by reduced accuracy for reporting a second target that occurred two

or three scenes after the first, given that the first target was accurately reported. The attentional blink was reduced for urban scenes compared to natural scenes, suggesting that the difference in scene type contributes to more efficient allocation of attention for urban scenes. To test whether this difference in the size of the attentional blink is accompanied by a difference in spread of attention between scene types, Experiment 2 used a similar RSVP task to Experiment 1 but added a peripheral target detection task. A black dot was placed around the corner of some of the images and participants reported at the end of each trial if a dot was present or not. Dots were better detected for natural scene trials, suggesting that participants have a broader spread of attention for natural scenes. The current results suggest that urban scenes lead to a narrowed attention allocation that allowed participants to more efficiently prioritize and identify targets compared to a broad spread of attention when viewing natural scenes.

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The Decisional Blink? Response criterion and the attentional blink paradigm.

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The Attentional Blink (AB) is the impaired detection of a target in a stream of rapidly presented objects (T2) when it follows the presentation of another task-relevant object (T1) by ~200ms. This paradigm has been widely used to measure attentional control in diverse populations (eg, meditators, gamers). AB magnitude is typically assessed by computing the hit rate for T2 following correct T1 identifications. Thus, savvy observers could eliminate their AB by simply reporting that T2 is always present (ie, by employing an extremely liberal response criterion). Here, we use signal detection theory to measure the AB and show that AB magnitude is confounded by response criterion when calculated with hit rate only, the common analytical approach. 39 participants completed 160 test and controls trials of the AB paradigm. Test: participants reported the identity of T1 (a single white letter in a stream of black letters) and detected T2 (an X that was present or absent). Control: T1 was ignored and only the T2 detection judgment was reported. In both trial types, the temporal location of T2 was manipulated (8 Lags, 100-800ms). We replicated the classic AB effect: hit rates were reduced in test compared to control trials, reaching their lowest point at Lag 2. d′, which takes hits and false alarms into account, was also significantly reduced in test compared to control trials. Response criterion also differed between test and control trials, replicating the Neyman-Pearson objective. Finally, the degree to which criterion changed between control and test was strongly and negatively correlated with the magnitude of classic AB effect. If one’s goal is to compare the magnitude of the AB between groups or after an experimental intervention in a way that isolates perceptual factors from decisional ones, researchers are urged to abandon the currently widespread analytical approach.

Perception and Action: Navigation

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Threshold versus Accumulator Frameworks of Manual Steering and Automation Takeover Initiation

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Vehicle control is possible because the human nervous system is capable of producing complex sensorimotor actions. Drivers must monitor errors and initiate steering corrections of the correct magnitude and timing to maintain safe lane positions. The perceptual mechanisms determining how a driver processes visual information and initiates corrections remains unclear. The perceptual-motor action literature suggests two potential alternative mechanisms for responding to errors: (i) perceptual evidence (error) satisficing fixed constant thresholds (Threshold), or (ii) the integration of perceptual evidence over time (Accumulator). To distinguish between these mechanisms three experiments were conducted using computer generated steering correction paradigms. In the first two experiments, drivers (N=20) steered towards an intermittently appearing ‘road-line’ that varied in position and orientation with respect to the driver’s starting position and

trajectory respectively. In the third experiment (N=50), silent automation failures were induced at varying severities. Drivers had to disengage automation and initiate steering to avoid exceeding lane boundaries. Threshold and Accumulator accounts predicted different steering patterns responding to these errors: a Threshold account predicted a fixed absolute error response across conditions regardless of the rate of error development, whereas an Accumulator account predicted that drivers would respond to larger absolute errors when the error signal developed at faster rates. Results in all three experiments show that drivers responded faster, responded to larger quantities of error, and steered with greater magnitude, as the rate of error signal development increased. These findings are in line with an Accumulator account, thus we propose that models of steering and silent failure takeovers should integrate perceptual evidence over time to capture human perceptual performance.

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The coordination of gaze and steering behavior in drone-racing pilots during high-speed flight

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While locomoting through natural environments, humans coordinate their gaze and steering to efficiently sample the visual information needed to guide movement. The coordination of gaze and steering during high-speed movement has been extensively studied in the context of automobile driving. Theoretical accounts that have emerged from this work, such as the waypoint fixation hypothesis (Lappi & Mole, 2018), capture behavior during self-motion along an explicit, well-defined path over a flat, obstacle-free ground plane. However, humans are also capable of visually guiding self-motion in all three dimensions through cluttered environments that lack an explicit path, as demonstrated during drone racing. The aim of the present study was to explore the gaze and steering behavior of drone pilots as they maneuvered at high speeds through a dense forest. Subjects were instructed to fly a simulated quadcopter along a race course embedded within a forest-like virtual environment built in Unity. The environment was viewed through an HTC Vive Pro head-mounted display while gaze behavior was recorded using a Pupil-Labs VR/AR extension. Drone position, orientation, and controller outputs were recorded by Microsoft AirSim. In the control condition, the race course was defined by an explicit path and there were no obstacles that impeded movement along the path. The task in this condition was similar to steering an automobile along a winding road and allowed for the fixation of waypoints. We compared gaze and steering behavior in the control condition to other conditions in which the waypoint fixation strategy was less suitable, such as when the course was defined by a series of gates rather than a path and when obstacles (trees and overhanging branches) were present that had to be avoided. Discussion focuses on how gaze and steering behavior are adapted to task demands during high-speed steering through cluttered environments.

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Gaze distribution around footholds in rough terrain.

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In rough terrain, walkers must use vision to select viable paths and to find suitable footholds within the time frame allowed by the gait cycle. How is this visuo-motor loop controlled? Recent work demonstrated that in rocky terrain, walkers spend most of the time fixating the region 2-3 steps ahead, which allows them to take advantage of the passive dynamics of the body, and stay close to the energetically optimal gait (Matthis et al, 2018). However, in that study it was not possible to accurately estimate fixation and footplant locations, as errors were introduced by projecting gaze onto a flat ground plane. We have recently been able to improve these estimates using a novel animation technique called photogrammetry to create 3D representations of the terrain using video footage from the Pupil Labs scene camera. In combination with eye tracking and IMU-based body tracking, photogrammetry allowed us to intersect the gaze vector with the actual 3D location of the walking surface. We were also able to more accurately locate the placement of the foot. This method allows for more accurate localization of gaze relative to foothold locations, and also eliminates IMU

drift. We analyzed 6 walks on rocky terrain for each of 3 subjects. For the different subjects, gaze was distributed around the upcoming footholds (2 and 3 steps ahead) with a standard deviation ranging between 17-21cm for the different subjects (approximately a foot-length) in the direction of travel, but only 3.3-5.1 cm laterally. When gaze is 2-3 steps ahead, two standard deviations covers approximately 16 deg by 4 deg. Thus walkers allow more flexibility in gaze location along the travel path and are presumably using information from the parafoveal retina to guide the choice of foothold at least some of the time in rocky terrain.

Acknowledgements: NIH grants EY05729 and EY 028229

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The neighborhood of interaction in human crowds is explained by visual information

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Most models of collective motion are based on the physical positions and velocities of others in a neighborhood of interaction. For example, in our physical model (PRSB 2018, CDPS 2018) a pedestrian matches the average heading direction and speed of neighbors, weighted by their distance: weights decay gradually to the nearest neighbor, and more rapidly in the crowd. Recently we developed a visual model, in which a pedestrian's heading and speed are controlled by nulling the average angular velocity and optical expansion of neighbors, which are sinusoidal functions of eccentricity (VSS 2017, 2019). Neighbor influence is proportionally reduced by partial occlusion (ICPA 2019). Here we use these models to simulate data from three experiments with no free parameters. Exp. 1: Participants "walked with" a virtual crowd of 12 neighbors. A subset of neighbors (0, 3, 6, 9, or 12) changed direction (±10˚) or speed (±0.3m/s) on each trial, and the participant's walking speed and heading were recorded. The RMSE of heading was 1.97˚ for the visual and 2.08˚ for the physical model (BF=1.90, anecdotal evidence for visual). The RMSE of speed was 0.063m/s and 0.064m/s, respectively (BF=2.43, anecdotal for visual). Exp. 2: The distance of the virtual crowd was varied (2, 4, or 6m), and one row (near, middle or far) changed direction (±10˚). The RMSE of heading was 2.5˚ and 3.6˚, respectively (BF>>100, decisive for visual). Exp. 3: A human 'swarm' (N=10, 16, 20) walked together for 2min trials. We simulated thirty 10s segments, modeling one participant with input from neighbors. The RMSE of heading was 15˚ and 29˚, respectively (BF=6, substantial for visual). Remarkably, the gradual decay with distance is explained by Euclid's law, while the rapid decay is an additional effect of occlusion. The neighborhood of interaction is thus explained by visual information, eliminating explicit distance terms.

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Third-order Motion, Not First-order Motion, Is Used to Control Locomotion When Following a Crowd

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Humans locomote in complex dynamic environments and constantly interact with other pedestrians. We investigate whether the visual-motor system relies on first-order motion (motion energy) or third-order motion (tracking bounded 'figures') (Lu & Sperling, 1995) to control walking when following a crowd. One might expect that visual-motor processes are driven by 1st-order motion, as in insect flight control; on the other hand, interacting with other pedestrians could require tracking their boundaries, consistent with 3rd-order motion. To dissociate the two, we presented 'reverse-phi' motion (Anstis, 1970) in a virtual-reality display during walking. Participants (N=12) wore a head-mounted display (Samsung Odyssey+, 110º FOV) and were asked to "walk with" a crowd of virtual objects. The simulated 'crowd' consisted of 9 vertical rectangles (1.6m x 0.5m) mapped with a grayscale granite texture. The 'crowd' initially moved forward at 1.2 m/s, then we briefly perturbed (for 2s) the motion of a subset of the objects (0, 6, 9). With a heading perturbation (±20˚), the subset moved left or right; with a speed perturbation (±0.2 m/s), the subset optically expanded or contracted. During the perturbation, object texture underwent 4-frame reverse-phi motion, such that the 1st-order motion moved in the Same or the Opposite direction as the 3rd-order motion. In the Control condition (subset=0), all objects continued moving forward at a constant speed, with no contrast reversal. The participant's walking direction and speed were recorded. Responses were as predicted by 3rd-order motion in all conditions. The mean heading response was 7.38° in the Same condition and 7.93° in the Opposite condition, in the 3rd-order direction ($p<.001$). The mean speed response was 0.069m/s in the Same condition and 0.071m/s in the Opposite condition, also in the 3rd-order direction ($p<.001$). The results indicate that human locomotor interactions are controlled by 3rd-order motion, consistent with tracking moving and expanding boundaries.

Acknowledgements: Funding: NIH R01EY029745

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Visual Models of Collision Avoidance with Moving Obstacles

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Despite years of studying collision avoidance in robotics, computer animation, and traffic engineering, there is still no biologically plausible model of how a human pedestrian avoids a moving obstacle. Most models are based on the physical 3D position and velocity of the object as input, rather than the visual information available to a moving observer. As a pedestrian approaches a moving obstacle, a collision is specified by a constant bearing direction together with optical expansion of the obstacle. We developed a series of dynamical models of collision avoidance that use changes in bearing direction, visual angle, or distance, and the participant's preferred walking speed, to modulate control laws for heading and speed. We fit the models to human data and attempted to predict route selection (ahead or behind the obstacle) and the locomotor trajectory. The data came from a VR experiment in which a participant (N=15) walked to a goal at 7m while avoiding an obstacle moving on a linear trajectory at different angles (±70°, ±90°, ±100° to the participant's path) and speeds (0.4, 0.6, 0.8 m/s). Model parameters were fit to all data. Error was defined as the mean distance between the predicted and actual human positions. Behavioral Model 1 takes the derivative of bearing direction and distance as inputs; Visual Model 4 takes the derivatives of bearing direction and visual angle as inputs. The mean error of Model 4 (M=0.184m, SD=0.169) was significantly smaller than that of Model 1 (M=0.195m, SD=0.172), $t(1004)=6.89$, $p < 0.001$. Route selection accuracy was comparable (Model 4, 84.0% correct; Model 1, 83.6% correct). Together, the results show that a visual model based on optical information can capture collision avoidance at the level of individual trajectories better than a behavioral model based on physical variables.

Acknowledgements: Funding: NIH R01EY029745

Poster Session B > Perception and Action: Navigation > Poster B87

Walking speed and trunk sway: Influence of an approaching person's gait pattern on collision avoidance

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Gait patterns provide a rich source of person-specific information such as age, sex, identity, and vulnerability. However, it is unknown to what extent person-specific gait information can affect collision avoidance behaviours with an approaching "person". We sought to determine whether young adults' spatiotemporal avoidance behaviours were affected by changes to a virtual agent's gait parameters (i.e., speed or trunk sway). In a virtual environment (FOVE head-mounted display; 70Hz), young adults (n=21) walked along an 18m pathway towards a goal while avoiding an approaching virtual agent. The agent's walking speed and trunk sway magnitude were a multiples of each participant's average speed or sway: fast (x1.5m/s), normal (matched), or slow (x0.8m/s); large (2x), normal (matched), or small (0x) respectively. The agent was non-reactive and walked straight forward at a constant speed. Participants' kinematics were recorded (Qualisys; 120Hz) to examine avoidance behaviours of initiation of path deviation and medial-lateral clearance at the time of crossing. Statistical analysis revealed that participants initiated a path deviation (i.e., estimate of time-to-contact, TTC) significantly earlier ($F(2,40)=11.31$, $p<.001$, $f=.69$) when the agent was walking fast (M=3.93s, SD=.56) as opposed to normal (M=4.31s, SD=.33) and slow (M=4.41s, SD=.44) walking speeds. However, the agent's trunk sway magnitudes did not affect participants' initiation of path deviation or medial-lateral clearance at crossing. Participants appear not to use temporal information to initiate an avoidance, but rather a point in space (i.e., TTC was affected by approach speed) due to awareness that the agent was non-reactive and always approaching. The agent's sway magnitude did not affect medial-lateral avoidance behaviours most likely because there was little observable difference between conditions (i.e., ~3° normal sway). Conceivably, the study's environmental conditions may underrepresent people's behaviours in real-world. Future work is needed to understand the perception of an approaching person's gait characteristics on collision avoidance.

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Where do I go from here?: Spatial navigation strategy and disorientation when switching environments

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Deciding which way to turn when leaving a store requires one to be spatially oriented when switching environments, but it is unclear how orientation is maintained. There are two potential navigational strategies: (1) egocentric: environmental locations are encoded in relation to the self; and (2) allocentric: external cues are referenced independent of the self. Previous research has shown these strategies arise from separate systems. Here, we examined whether these two systems interact and whether reliance on different cues changes when switching from one environment to another. The present study investigated how different environmental cues and degree of disorientation affects spatial navigation during an environment switch (from indoor to outdoor). For each trial, participants viewed a simulation of a walk down a city street. Halfway up the street, participants entered a building and underwent a disorientating path of either low or high complexity. Upon exiting, participants chose which way to turn to continue. In order to examine the reliance on environmental cues when exiting, the view of the street was manipulated to be mirror reversed in half the trials. Adherence to the street view indicated a reliance on allocentric strategies, whereas failure to adjust to the view indicated a reliance on egocentric strategies. Following their choice, participants were presented with the view down the street and prompted to confirm or change their choice. Results revealed that the mirror change was initially disregarded, but corrected based on the subsequent street view. Further, we found an interaction between path complexity and mirror conditions: RT was longer for mirrored than original views with low path complexity, but faster when high. This pattern indicates that although both strategies are engaged when switching environments, their implementation is largely asynchronous, such that egocentric dominates early and allocentric dominates continuous control of navigation.

Perception and Action: Reaching, pointing and grasping 1

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Modelling trajectories from choice reaching experiments through submovement decomposition

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Previous studies have shown that reaching movements can be influenced by attentional selection processes. Critical evidence for this effect stems from reach trajectories in colour-oddity tasks. These experiments showed that the modulation of reach curvature is linked to colour priming—i.e., colour repetitions lead to smaller curvatures compared to trials where the target colour switches (e.g., Song & Nakayama, 2008; Moher & Song, 2016). Following this evidence, Heinke and colleagues developed a neurologically inspired robotics model for colour priming (Strauss et al., 2015). Critically, the model shows that attentional selection processes easily leak into movement planning causing the curvature effect. Here, we capture this leakage effect through the assumption that reaching movements are composed of submovements (e.g., Flash & Henis, 1991; Friedman, Brown, & Finkbeiner, 2013). Submovements are defined as

discrete, ballistic movements with predetermined amplitude, direction, and duration prior to their onset. Each submovement is a straight-line trajectory but their superposition can create a curved trajectory. Friedman et al. (2013) showed that perceptual decision-making processes are reflected in submovements. In this research, we demonstrate that submovements provide deeper insights into the curvature effect. For instance, we found that switch trials are characterized by more submovements. Hence, submovement decomposition reflected attentional selection processes in choice reaching tasks. Future work will aim to analyse the timing of submovements e.g., at what point of time the submovements which create the curved trajectories occur. These timings should reflect the timing of attentional selection.

Acknowledgements: This work is funded by a collaborative grant schema (US-NSF BCS-1849169 and UK-ESRC ES/T002409/1)

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Motor adaptations for object size perception and grasping

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Our research aimed to evaluate whether size perception and saccadic amplitude were affected before and after grasping a variable-size target under the presence (TF) or absence of tactile feedback (NoTF). Twenty-one volunteers (mean-age: 25.05±4.08years) participated. Volunteers were tested in four blocks of 30 trials. Each trial consisted of 3 consecutive phases: pre-grasping estimation, grasping and post-grasping estimation. During pre- and post-, participants were asked to perform a saccadic eye movement to a horizontal bar and manually indicate its horizontal size by extending index and thumb fingers. In the grasping phase, participants were instructed to make a grasping action towards the bar. While grasping, 30% of the trials had a random horizontal size perturbation, which meant a lengthening or shortening of 33% of the original size. In sixty trials, grasping action was assisted by TF implemented through mobile phone vibration motors. A motion caption system recorded and assessed participant's hand position. Participant's gaze was recorded by a mobile eye-tracker. During the post-estimation phase, the non-perturbation condition revealed an inverse relationship between saccadic amplitude and bar size ($r=-0.69$ and $P=0.03$, for both NoTF and TF). However, the same indirect relationship during shortening (NoTF: $r=-0.17$ and $P=0.66$; TF: $r=-0.56$ and $P=0.15$) and lengthening (NoTF: $r=-0.46$ and $P=0.25$; TF: $r=-0.24$ and $P=0.50$) conditions was not found. Grip aperture showed a significant correlation in all post-phase conditions for both NoTF and TF ($r>0.93$ and $P<0.001$). Comparing pre- and post-phase values, both NoTF and TF evidenced that lengthening condition caused a significant reduction in grip aperture ($p=0.02$ and $p=0.04$, respectively), whereas shortening did not reveal significant changes ($P=0.74$ and $P=0.53$). A significant increase in saccadic amplitude after shortening condition in TF was observed ($P<0.001$), but not in NoTF ($P=0.22$). Horizontal target size perturbation and tactile feedback during grasping execution modifies size perception and saccadic amplitude.

Acknowledgements: This work was supported by the European Grant PLATYPUS (Grant Agreement No 734227), a Marie Sklodowska-Curie RISE initiative.

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Bimanual grasping adheres to Weber's law

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While Weber's law seems to hold true for most stimulus attributes and sensory modalities, so far it has consistently been found that it is violated in grasping. One suggested explanation for the absence of Weber's law in grasping is that biomechanical constraints of the hand may mask its effect. However, Ganel et al. (Sci Rep 7, 6467, 2017) reported that Weber's law is also violated in bimanual grasping. Here, we revisited the question of whether the elimination of biomechanical constraints results in grasping behaviour consistent with Weber's law by using a modified and extended version of the bimanual study by Ganel et al. (2017). As stimuli, we used cubes with different side length (16, 24, 32, and 40 cm). Participants (N=20) performed two different tasks: bimanual grasping (action task) and bimanual estimation

(perceptual task). In the action task, participants were asked to grasp and lift a cube with both hands. In the perceptual task, they were asked to indicate the size of a cube with their hands as accurately as possible. For each of the two tasks, there were two different conditions. In the “central” conditions, the distance between the start positions of the hands and the edges of the cubes increased with cube size, whereas in the “side” conditions, this distance remained constant. All tasks were performed visually open-loop. JNDs were estimated using the standard deviations of the maximum-hand apertures in the two tasks, respectively. We found adherence to Weber’s law in both bimanual estimation and grasping and independent of the hands’ start positions. These results are in direct conflict with those reported by Ganel et al. (2017). We discuss possible explanations for the divergent findings and encourage further research to establish whether or not actions still violate Weber’s law when biomechanical constraints are removed.

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Further evidence that people do not rely on allocentric information to guide their movements when the target is visible

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Many everyday tasks involve moving one’s fingers to a target. Previous research has shown that such movements can rely on both egocentric (object-to-self) and allocentric (object-to-object) visual information. However, the use of allocentric information to guide ongoing movements towards continuously visible targets is yet to be demonstrated. We previously found no evidence for the use of allocentric information in a task where participants intercepted a visible target using a cursor that represented their finger position, even though the finger was moving in a different plane than the cursor. On each trial there was either an independent perturbation of the target, cursor or background, or the simultaneous perturbation of all three task components. In the latter condition the relative positions of the task components remained constant such that relying on allocentric information would be advantageous in avoiding unnecessary adjustments to the ongoing movement. Participants responded to the simultaneous perturbation in accordance with how we would expect them to respond if they dealt with each individual perturbation egocentrically. In the present study, we modified the task such that participants’ finger position determined the velocity rather than the position of the cursor. Doing so further dissociates finger movements from cursor movements. For example, when the finger stops moving, the cursor does not stop moving but continues to move at the prevailing velocity. Participants still responded to the simultaneous perturbation of target, cursor and background. Again they did so in accordance with how they responded to each perturbation individually. This supports the idea that allocentric spatial information is not used to control ongoing actions when the target is visible.

Acknowledgements: This work was supported by the Netherlands Organisation for Scientific Research (NWO) under project number 464.18.111 awarded to Eli Brenner

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Prediction of visual target positions from movement kinematics

View Poster | Play Video | Visit me in Gather.Town Dolphin Room on Sunday 8:00 am - 10:00 am EDT

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Arm movements towards visual reaching targets provides a rich source of cues about final action goals and intentions. In the present research, we investigated how early during action execution movement kinematics can predict static and shifted visual target positions. Visual targets were distributed at different directions and depths of the visual space and we assessed whether the visual target representation shares the same temporal structure in the two spatial dimensions along the movement execution. Specifically, we analysed the arm trajectories while 13 participants were executing a visually guided reaching towards targets located at different depths and directions with respect to the body in peripheral viewing conditions. The visual targets could remain static during the entire duration of the movement or could shift along the horizontal (direction) or the sagittal dimension (depth) once the movement was started. In order to predict the position of static and shifted visual targets, we discretised the continuous horizontal and vertical component of movement trajectories in spatial intervals and we used a Linear Discriminant Analysis (LDA) classifier to extract classification accuracies describing how early it is possible to make reliable estimates about visual target positions. The

results show that the horizontal trajectory component (of both pointing finger and wrist) was predictive only for the direction of static and shifted visual targets. In contrast, the vertical trajectory component of pointing finger and wrist was predictive only for the depth of static and shifted visual targets. In both cases, wrist trajectories showed higher classification accuracy with respect to the pointing finger with increasing accuracy of all visual target positions starting from the 50% of movement. These findings suggest that it is reliably possible to extract visual target information from movement kinematics well before the conclusion of action without significant difference in temporal structure between direction and depth dimension.

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Perception and Action: Virtual environments 1

Poster Session B > Perception and Action: Virtual environments 1 > Poster B94

The effect of airflow on (visually induced) motion sickness during a simulated driving task

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Driving simulators are highly valuable tools for research, rehabilitation, and training purposes, but are also known for commonly causing simulator sickness, a special form of traditional motion sickness that is primarily driven by stimulation of the visual system. Simulator sickness can increase the users' rate of terminating a simulated driving session dramatically and can be as high as 77%. Although the alleviation of simulator sickness is crucial for ensuring the users' well-being and guaranteeing the quality of driving performance data, reliable methods that successfully reduce simulator sickness have not yet been identified. Thus, the goals of the present study were (1) to investigate the efficacy of airflow as a countermeasure against simulator sickness and (2) to explore the relationship between airflow and the participants' subjective comfort. Twenty-four healthy young adults (14F, 10M) were engaged in a 25.5km long simulated driving task using The KITE Research Institute's high-fidelity driving simulator. To study the effect of airflow on simulator sickness, car vents were directed to generate airflow that directly passed over the driver's skin (direct airflow condition; n = 11) or towards the ceiling of the car (indirect airflow condition, n = 13). Simulator sickness was assessed using the Fast Motion Sickness scale and the Simulator Sickness Questionnaire. Results suggested that simulator sickness was reported to be mild on average (mean FMS score of 5.31) and did not differ between the two airflow conditions. However, participants in the direct airflow condition reported to feel colder ($p = .019$) and to be more uncomfortable ($p = .044$) than participants in the indirect airflow condition. Taken together, our findings indicated that both types of airflow had similar effects on simulator sickness, but that the use of indirect airflow may be preferred to direct airflow as it promotes greater subjective comfort while achieving similar results.

Poster Session B > Perception and Action: Virtual environments 1 > Poster B95

A Toolbox for Perception and Action Experiments Using the Vizard VR Platform

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Virtual Reality (VR) is gaining momentum in vision science due to its unprecedented potential to study the behavior of active participants in naturalistic but still well-controlled environments. This approach is further facilitated by the growing availability of VR devices with built-in eye tracking, allowing simultaneous recording of gaze and movement behavior. Rendering engines such as Vizard, Unity, and Unreal have made it simple to create virtual environments, but most come ill-equipped out of the box to handle the typical structure of a sensorimotor experiment, such as looped presentation of structured behavioral 'trials' and capture of continuous behavioral data. This leads to code duplication and re-implementation of the same components by multiple labs and hampers open science and reproducibility efforts. Recently, some research groups have published toolboxes for the Unity platform that facilitate the creation of behavioral

experiments. Based on experience from our lab, we here present a similar toolbox for the Vizard VR platform, which is widely used in perception and action research. Using our toolbox, a researcher can implement a behavioral experiment including eye and hand movement recording with comparatively little Python code. The experimental structure can be generated programmatically or imported from a file, and the toolbox takes care of randomizing, presenting, and recording trials. Results are saved in standardized file formats such as CSV and JSON for ease of analysis. Additionally, our toolbox allows for easy online recording and calibration of gaze and motion tracking data using any hardware device supported by Vizard. We highlight the structure and central features of our toolbox using the example of a goal-directed reaching task in VR. This is accompanied by the release of the toolbox code as open source.

Impact of development on spatial cue processing

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When we navigate in urban environments, we face multiple landmarks incorporated in street-like layouts with varying geometry. Young adults are known to prefer landmarks to reorient in space, whereas older adults preferentially rely on geometric cues. On the other side of the lifespan, young children also prefer geometry, but little is known about how spatial cue processing changes during development. This study investigates what types of spatial cues (landmarks vs. geometry) are used by children of different ages when bearings are lost. So far, 24 children (9-11 yo, 13 males) were included in the study. Children were requested to solve a goal-oriented navigation task by finding an invisible goal in a rectangular virtual environment. A 3D-immersive virtual reality headset allowed children to freely move in space and integrate multisensory percepts as in near-naturalistic conditions. After 8 learning trials, the whole configuration of landmarks was rotated, creating a conflict between landmark and geometry cues. Subsequently, children’s cue preference for spatial orientation was tested during 5 probe trials. Data show that 50% of the children spontaneously reoriented according to the geometric shape of the environment, whereas the others preferred landmarks. Task performances were comparable between the two groups, suggesting that goal location coding based on geometry or landmark cues was equally efficient. Data also suggest that visual exploratory behavior during learning could predict cue preference in test phase. These results suggest that children of 9-11 years of age are in the middle of development in terms of spatial cue processing, and therefore predict specific cue-preference patterns for younger and older children. This prediction is currently being tested in a follow-up study in our laboratory. This work will help to infer the psychometric function describing the relation between spatial cue preference and age during development.

Attention: Neural

Integrating top-down and bottom-up attention control factors: an EEG study

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Attention can be controlled by bottom-up, stimulus driven, and top-down, goal-driven sources. The current study aims to examine how the different sources are integrated, using known EEG components related to attention - N2pc and Pd. These components are thought to reflect target selection and distractor suppression, respectively. We used endogenous cues for top-down attention control and salience for bottom-up attention control in a visual search task. In Experiment 1 participants reported the orientation of a tilted target preceded by a valid or neutral cue. In Experiment 2 the task was to report the location (up or down) of a small gap within the target. On some of the trials the target appeared in a different color, rendering it salient. On the other trials, the target appeared with or without a salient distractor. Our results showed cueing effects on RT and accuracy in both experiments, demonstrating a general facilitation of responses to validly cued

targets. Salient targets were not detected faster than non-salient targets, and a salient distractor worsened performance. N2pc and Pd were found only in trials where the target was preceded by a neutral cue In Experiment 1. No such cueing effects were found in Experiment 2. The lack of N2pc in the validly cued trials in Experiment 1 suggests that no further engagement of attention was required by the search or the task. The evidenced Pd following a valid cue suggests the involvement of attention in the suppression of a salient distractor. The result of Experiment 2 suggests that task demands masked the effects that would otherwise be evident.

Poster Session B > Attention: Neural > Poster B98

Tuned normalization bandwidth is unaltered by attention

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In visual cortex, divisive normalization is modulated by features, such as orientation similarity: surround suppression is more potent when the surrounding orientation content is collinear with the orientation content of the center, compared to when the surround is orthogonal to the center. Correspondingly, neural responses to orthogonal stimuli are stronger than responses to stimuli in a collinear arrangement. Here, we provide a closer characterization of this feature-tuned aspect of normalization in human fMRI. Using full-field stimuli composed of alternating wedges filled with band-pass filtered noise enabled us to vary orientation differences between neighboring components in 15° increments between 0° and 90°, and examine whether orientation-tuned suppression strength changes as a function of orientation similarity. In agreement with previous research, we demonstrate that strongest BOLD response is seen for orthogonal and weakest BOLD response for collinear configurations, gradually decreasing as orientation similarity increases. We quantified the bandwidth of tuned normalization by fitting a Gaussian function to the tuned normalization curves for each subject. Having established this measure, we next asked how attention modulates the bandwidth of tuned normalization. The normalization model of attention posits that divisive normalization facilitates attentional modulation, and prior work has shown that stronger divisive normalization produces stronger attentional modulation. Would directing attention to the stimulus also affect the bandwidth of tuned normalization? In a second experiment, participants viewed similar stimuli while either performing a task at fixation (drawing attention away from the stimulus) or detecting color changes within the oriented stimulus (directing attention to the stimulus). We replicated our previous results – BOLD activation gradually increased from collinear to orthogonal. Our results demonstrated larger attentional effects for the collinear configuration, consistent with a previous finding from our lab. However, we find that tuned normalization bandwidth appears to remain unchanged with attention.

Poster Session B > Attention: Neural > Poster B99

Reduced learning of implicit expectations in behavior and early visual cortex responses in autism

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Inspired by recent predictive processing models of autism, we investigated if individuals with autism developed implicit expectations and typical surprise responses to stimuli engaging low-level visual processing and targeting the early visual cortex. Specifically, we presented sine-wave gratings at two visual field locations known to evoke C1 event related potential (ERP) components and, unbeknownst to the participant, created an orientation/location contingency (i.e., some orientations were presented 80% of the time at a particular location). We collected high-density EEG responses, behavioral orientation adjustment responses and confidence measures as a probe of metacognition. We tested 54 adult participants divided into two groups (autism vs. control). Our results replicated the work of Jabar et al. (2017) showing that high probability orientations are associated to lower C1 amplitudes and smaller errors in the adjustment task. For group comparisons, only the control group showed significant differences between high and low probability trials at both EEG and behavioral measures. This suggests that individuals with ASD were unable to learn implicit expectations behaviorally and neutrally, at the level of the early visual cortex (i.e., sharpening the responses to frequent stimuli or responding differently to expected and unexpected stimuli). This suggests a deficit in perceptual learning and/or feature-based attention at the level of the early visual cortex for individuals with autism, which we interpret as altered learning of contextual priors in light of current predictive coding models of autism. Interestingly, these results run counter findings of intact implicit learning in several other tasks, as well as intact (or even improved) low-level processing in autism. However, the combination of implicit learning and low-level perception (as well as the measurement of the expectation-based modulation of the early C1 component) is novel to the field, and may explain the divergence. More extensive analyses of the metacognition measures will also be discussed.

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Poster Session B > Attention: Neural > Poster B100

Extracting Evidence for Neural Rhythms from Behavioral Measurements

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Our sense of every-day visual experience is continuous and seamless, yet neurophysiological and psychophysical evidence suggests that visual processing operates with an intrinsically paced regularity. In the laboratory, signatures of rhythmic oscillations emerge from analyses of EEG recordings and from analysis of behavioral performance (e.g., detection accuracy) measured at parametrically varied time points. Recently, we devised a procedure based on conventional spectral analysis that can disclose rhythms within incidences of perceptual dominance durations during binocular rivalry. With these kinds of data, it is impossible to control time elapsed until the terminal behavioral event. Instead, we relied on an enormous data set (average of 4,364 durations/condition) to recover probabilities of behavioral events at parametrically varied time points, allowing generation of probability density histograms. Such large amounts of data, however, are typically not achieved in human behavioral studies. To overcome this limitation, we have developed a computational procedure for analysis of rhythms (CPAR) that uses the differences in the amount of variance explained by a cumulative distribution function (CDF) and by a transformed CDF which incorporates rhythmic oscillations. To confirm the validity of CPAR, we generated two durations data sets using a modified random walk model: one set containing 200 durations/condition for CPAR, and the other set containing 1,000 durations/condition for spectral analysis. With these simulated data, CPAR achieved comparable results to those obtained using spectral analysis with a considerably smaller data set. We then analyzed publicly available human behavioral data (https://osf.io/q6vmd) with CPAR and with spectral analysis, demonstrating that CPAR outperforms conventional spectral analysis when analyzing human response time data containing just a few hundred durations per condition. We conclude that CPAR offers an efficient, sensitive means for extracting rhythms embedded in durations data.

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Poster Session B > Attention: Neural > Poster B101

Flaws in data binning for population receptive field analyses

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Data binning can deal with overplotting and noise. As such, it has become integral to population receptive field (pRF) analyses aimed at contrasting visual field maps with many observations. However, such differential data binning is flawed if the same observations are used for binning and contrasting. This creates circularity, eventually biasing noise components. To expose this flaw, we perturbed pRF position estimates of an empirical visual field map with random Gaussian noise. We repeated this to simulate an Interest, Baseline, and Independent condition. The Interest and Baseline condition can be regarded as different attention conditions and the Independent condition as a replication of the Baseline condition – to give but one example. We then binned pRF positions from the Interest and Baseline condition and calculated bin-wise means. The binning was based on pRF positions from any of the three conditions. Since there were no systematic differences between conditions, the bin-wise means for the Interest and Baseline condition should always coincide. Although this was true when using the Independent condition for binning, artifactual differences occurred when using the Baseline condition instead. Strikingly, these differences flipped when using the Interest condition for binning. This bidirectionality is characteristic of regression to the mean and occurred because the same condition (e.g. Baseline) was used for contrasting and binning. This circularity skewed the bin-wise noise components for this condition on average, rendering the bin-wise means more extreme. As a consequence, the bin-wise means in the other condition (e.g. Interest) regressed – by statistical necessity – to the overall mean. This regression artifact replicated with empirical repeat data and was modulated substantially by data cleaning and heteroscedasticity, rendering it easy to mistake for a real effect. Consequently, flawed differential binning may have resulted in spurious claims about the plasticity of pRFs in previous research.

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Poster Session B > Attention: Neural > Poster B102

Lateralization of spontaneous alpha-band oscillations biases contrast perception

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Perceptual decisions depend both on the features of the incoming stimulus and on the ongoing brain activity at the moment the stimulus is received. Specifically, trial-to-trial fluctuations in the power of prestimulus alpha oscillations (~8-13 Hz) are associated with fluctuations in sensory detection bias, i.e. the tendency to report stimulus absence or presence. It is currently unknown whether prestimulus alpha oscillations affect only such overt reports, or even modulate our subjective perception. To fill this gap, we used a contrast discrimination task in which subjects reported which of two gratings – one in each hemifield – was perceived as having stronger contrast. Our EEG analysis showed that subjective contrast was reduced for the stimulus in the hemifield represented in the hemisphere with relatively stronger prestimulus alpha power. This effect of alpha lateralization is consistent with previous studies showing that strong spontaneous alpha power suppresses neuronal and sensory excitability. Moreover, by applying a Common Spatial Pattern analysis on the prestimulus window (500 ms before stimulus onset) in the alpha range, we were able to decode the reported subjective contrast independent of the stimuli's objective contrast difference. Interestingly, a classifier trained to decode the hemifield with stronger subjective contrast based on spontaneous alpha lateralization could not decode attended hemifield based on cue-induced alpha lateralization and vice versa. This lack of generalization suggests that spontaneous and cue-induced lateralization are different phenomena.

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Poster Session B > Attention: Neural > Poster B103

The N2pc Component Does Not Always Precede Eye Movements

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Typically, researchers distinguish between two mechanisms of selective attention in vision: covert attention and overt eye movements. A common technique to study covert attention has come from the N2pc ERP component. Although it is commonly assumed that shifts of covert attention automatically precede eye movements, few studies have directly investigated whether the N2pc component occurs before eye movements. In the current study, participants performed a simple visual search task. Unlike previous studies of the N2pc component, eye movements were allowed and were measured using an eye tracker. At analysis, the EEG data were timelocked to the onset of the first saccade and we assessed whether the first saccade was preceded by an N2pc component. In conditions that allowed participants to freely generate eye movements in service of search, we found no evidence of an N2pc component before the first saccade. In conditions where shifts of covert attention were required before an eye movement, however, we observed a robust N2pc component before the first saccade. Altogether, the current findings suggest that the N2pc component does not always precede overt eye movements during visual search.

Poster Session B > Attention: Neural > Poster B104

TMS entrains occipital alpha activity: Individual alpha frequency predicts inter-trial phase coherence

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Background: Parieto-occipital alpha rhythms (8-12 Hz) have been shown to underlie cortical excitability and influence visual performance. At rest, each individual has a peak intrinsic alpha frequency (IAF) of these rhythms. However, how the occipital cortex responds to an externally imposed alpha rhythm via transcranial magnetic stimulation (TMS) is an open question. Hypotheses: 10-Hz rhythmic TMS can entrain intrinsic alpha oscillators in the occipital cortex. Specifically, we predicted: (1) progressive enhancement of entrainment across time windows, (2) output frequency specificity, (3) dependence on the intrinsic oscillation phase, and (4) input frequency specificity to individual alpha frequency (IAF) in the neural signatures. Methods: We delivered 4-pulse rhythmic TMS at 10 Hz to entrain local neural activity targeting the right hemisphere V1/V2 regions while participants performed a visual orientation discrimination task. Concurrent electroencephalogram (EEG) recorded TMS-driven changes of local oscillatory activity. There were two control conditions: arrhythmic-active and rhythmic-sham stimulation, both with an equal number of pulses and duration. Results: The results were consistent with the first three hypotheses. Relative to both controls, rhythmic TMS bursts significantly entrained local neural activity. Near the stimulation site, evoked oscillation amplitude and inter-trial phase coherence (ITPC) was increased for 2 and 3 cycles, respectively, after the last TMS pulse. Critically, regarding hypothesis 4, ITPC following entrainment positively correlated with IAF, rather than with the degree of similarity between IAF and the input frequency (10 Hz). Entrainment did not affect visual sensitivity or criterion. Conclusions: We entrained alpha-band activity in occipital cortex for ~3 cycles (~300 ms) with our 4-pulse 10 Hz TMS protocol. IAF predicts the extent of entrained occipital alpha phase synchrony indexed by ITPC.

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How are theories of consciousness empirically tested? The Consciousness Theories Studies (ConTraSt) database

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How does consciousness arise from neural activity? Several theories try to answer this question, each providing fundamentally different interpretations of empirical data. Accordingly, no agreed-upon, comprehensive account of the neural substrates of consciousness has been achieved. To date, overviews in the field have relied mostly on qualitative reviews of the results and were typically written from the standpoint of one theory. Thus, a systemic, quantitative and theory-free review of studies is necessary to characterize the state of the field regarding these theories. Here, we conducted a comprehensive, quantitative and theory-neutral review of neuroscientific studies of consciousness (379 papers, reporting 418 experiments) that interpreted their findings as supporting/challenging one of four leading theories of consciousness: Global Neuronal Workspace, Integrated Information Theory, Recurrent Processing Theory and Higher Order Theory. Then, to identify biases in the way these theories were studied, the distributions of experiments to parameters extracted from each experiment were compared. Notably, all data is available in an open-access website with interactive plotting tools, to allow other researchers to conduct additional queries and analysis of the data. We found that some methodological choices of researchers increase the probability of their findings supporting certain theories. Also, we found that the field generally suffers from a strong confirmatory-bias, and that the majority of studies post-hoc interpret their findings concerning the theories, rather than designed a-priori to test their critical predictions, and that. Finally, when all findings were collapsed together, a highly variable pattern of spatial and temporal findings emerged, that is not predicted by any theory. To overcome these biases, potentially converging towards an agreed upon account, cross-talk between the theories is needed, testing each other's predictions and integrating ideas, as opposed to gaining

further affirmative results according to each theory's predictions.

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Attention: Spatial, features

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Prevalence effects in two feature dimensions

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Suppose you are making decisions about whether a greenish-yellow spot is green or not. If truly green spots are rare (low prevalence) and if you receive trial-by-trial feedback, you will be less likely to label ambiguous spots as green (classic low prevalence effect - LPE). If you do not receive feedback, the effect can reverse. You will be more likely to call the same spot green (prevalence induced concept change – PICC, see Levari et al, 2018). Now suppose that each item is defined by more than one feature as might be the case in complex decisions about suspicious spots on lung CT, for example. We used two-dimensional stimuli that varied in shape from "bouba" (rounded) to kiki (spikier) and in color (yellow-green). We could change the prevalence along one or both feature dimensions and we could provide feedback or not. Observers made 2AFC, "green kiki" versus "not green kiki" responses. When prevalence was reduced for one dimension (e.g. fewer green items, overall), effects were seen on the other dimension (i.e. the bouba/kiki boundary moved). Feedback produced LPE. Without feedback, PICC effect was seen, but more weakly. In Experiment 2, stimuli were drawn from separate green and yellow bouba-kiki continua. Observers made 3AFC responses ("green kiki", "yellow kiki", or "not kiki"). Prevalence of green kiki was decreased while prevalence of yellow kiki stayed the same. Changing the prevalence of green stimuli showed more effect on green than yellow stimuli, but prevalence effects, especially LPE, spread to yellow stimuli. PICC effects were again weaker in this experiment, implying that LPE and PICC effect, though coexist at low prevalence, may be mediated by distinct underlying processes. These results suggest that in complex real-world decisions, prevalence of one type of target may influence decisions about related, but distinct targets.

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Poster Session B > Attention: Spatial, features > Poster B107

Long-term selection history persistently enhances and suppresses visual features

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Statistical regularities in the environment can bias attention towards frequently encountered targets and away from frequently occurring distractors. While most research has investigated how experience with such regularities biases spatial attention, recent work suggests that experience with non-spatial features also influences attention. However, it is not clear whether experience-driven feature-based attention – especially for ignoring distractors – arises primarily from short-term reinforcement (e.g., inter-trial priming) or if it affects attention more durably (e.g., even when the statistical environment changes). To test this, we conducted experiments of learned feature-based enhancement (Exp. 1; N = 75) and suppression (Exp. 2; N = 75). Participants searched for a Landolt C of a target orientation (left or right gap) among seven distractor Cs (top or bottom gap). Each array contained four items in each of two colors, selected from among four possible colors. In Experiment 1, during a 432-trial training phase the target appeared in one color on 75% of trials (vs. 8% for the other three colors), with a subsequent 216-trial testing phase presenting targets equally often in all four colors. Despite not being informed of the probability manipulation, participants responded faster when targets appeared in the high-probability color versus when distractors appeared in that color during both training and testing phases. In Experiment 2, to test whether learned distractor color probabilities also benefit search performance, non-targets appeared more often in one color on 75% of trials. Similar to Exp. 1, participants responded faster when non-targets appeared in the high-probability color versus when targets appeared in that color during both training and testing phases, suggesting that the frequent non-target color was suppressed. These results demonstrate that statistical

regularities in the environment can persistently enhance selection of colors associated with targets and attenuate processing of colors associated with distracting information.

Acknowledgements: This research was supported in part by NSF Grant BCS-1850738.

Poster Session B > Attention: Spatial, features > Poster B108

Feature Avoidance: A Result of Probabilistic Attentional Guidance

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The broad categories of attentional guidance (top-down, bottom-up, and, more recently, selection history) have been widely used as heuristics to label different influences on attention, with the idea being those within a category should produce similar effects. However, additional traits within these broad categories may also play a large role in how a cue influences attention and the encoding of features. Prior work utilizing a continuous report delayed-estimation task to investigate deterministic top-down and salient bottom-up manipulations demonstrated swapping errors (i.e., the misreporting of a nontarget feature) and/or distortion errors (i.e., target responses biased either away from or towards a nontarget that had attracted attention), depending on the type of cue (Golomb et al., 2014; Dowd & Golomb 2019; Chen et al., 2019). The aim of the present study was to investigate how probabilistic cues (either top-down or experience-dependent) would impact attention and feature reporting, and whether we would observe patterns of errors suggesting similar attentional effects to those elicited by the previously studied deterministic top-down and bottom-up cues. To do this, we implemented a spatial probability cue or probabilistic arrow pre-cue to bias attention to one location before an array of colored items appeared and the target location was post-cued. Interestingly, instead of observing feature-binding errors such as swap errors or attraction to an attended nontarget, a unique effect emerged. Termed ‘feature avoidance’, when participants did not report the correct target color, they tended to misreport a color from the opposite side of the color-wheel to the color of the probabilistically cued nontarget, as if they were avoiding selection of that feature. This ‘feature avoidance’ seems to represent a phenomenon unique to probabilistic cues, and suggests a distinct influence of these types of cues on the attentional system compared to the previously reported shifting, splitting, or capturing of attention.

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Peripheral Cues Can Repulse Unbound Features Closer to Fixation

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Previous work has shown that, in the absence of focal attention, simple features (e.g., colors) can be misbound to incorrect locations. Here we show that attention-demanding cues in the periphery can repulse these features to be incorrectly seen at locations closer to fixation. Participants were cued with a shape (circle or square) either in the left or right periphery before seeing a horizontal array of diamonds in the center of the screen (a pair of diamonds on each side of fixation, each with one gray and one colored diamond). Participants reported the shape of the cue, and which two colors appeared at which of the four diamond locations. When the cue was absent or at fixation, participants were accurate in reporting the locations of both colored diamonds. But attending to peripheral cues created a perceptual repulsion, where colors on that side of fixation were consistently misperceived closer to fixation (and farther away from the cue). This illusion was found to be even stronger when the cue was presented in the right hemifield compared to the left hemifield, revealing an attentional hemifield asymmetry for the binding of simple features.

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Narrowing Down Spatial Attention Reduces Surround Suppression

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The effect of size and contrast on motion direction detection thresholds has been successfully explained by center-surround interaction. The effect of the spatial extent of attention on the thresholds, however, has not been systematically studied before. Here we studied this via a novel experimental design and developed a model to explain the behavioral results. The stimulus consisted of drifting sinusoidal gratings with 98% and 2% Michelson contrast. A central grating (diameter: 1.5°) was presented either alone or surrounded by an annular grating (width:2.5° or 9.2°) with a 1.3° gap between them. Drift direction in the central and annular gratings could be the same or opposite. There were two attention conditions. In the narrow attention (NA) condition, participants (N=10) were asked to attend the central grating and report its motion direction. In the wide attention (WA) condition, participants first reported the drift direction of the central grating, then reported whether the central and annular gratings drifted in the same direction. This was done to encourage the participants to widen their attentional fields. In each trial, the duration of the presentation was adjusted following an adaptive 1-up 3-down staircase procedure, based on the participants' judgments of the central grating drift direction. Results showed that surround suppression was significantly stronger in the WA condition compared to the NA condition. The magnitude of this effect increased as the stimulus size increased in 2% contrast condition, but did not change in 98% contrast condition. Next, we developed a model by incorporating the spatial extent of the attentional field in the normalization model (Reynolds and Heeger, 2009). The model could successfully predict the observed behavioral outcomes. These findings unveil the critical role of spatial attention on surround suppression and show that behavioral results and the effect of attention can be explained by a generalized normalization model.

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The role of attention and feature-space proximity in perceptual biases from serial dependence

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Recently seen items bias our perception ("serial dependence"), but the direction and magnitude of these biases vary. What determines this dependence between previous input and current percept? Attention and similarity (proximity in feature space) are two possibilities that have been discussed as potential influences on such biases. In four experiments, we investigated how attended (target) and ignored (distractors) visual search items bias the perceived orientation of an irrelevant test object while manipulating test-to-target and test-to-distractor similarity. In the first three experiments, participants searched for the line with the most distinct orientation from all other items ("odd-one-out" search) in blocks of 4-5 trials. To ensure that observers would have a precise representation of distractors, their orientations were repeatedly drawn from the same probability distributions within blocks. A test line was presented briefly after completing visual searches. Participants had to report its orientation by rotating an adjustment bar. We manipulated distance in the orientation space between the test line, the last target, and the mean distractor orientation in each block. In Experiment 4, target locations were additionally pre-cued to further decrease attention to distractors. The results indicate that ignored and attended items produce opposite (repulsive and attractive) biases upon the perceived orientation of an irrelevant item, but this effect was moderated by proximity in feature space. Attended items (targets) produced strong attractive biases when they were similar to the test stimuli but no biases when they were dissimilar. In contrast, ignored items (distractors) created weaker attractive biases when they are similar to the test items, but repulsive biases when they were dissimilar. Overall, we speculate that our results provide a glimpse into the bag of tricks that the visual system uses to stabilize visual perception over time and that both attention and similarity affect biases in perception.

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Feature Competition Modulates the Profile of Feature-based Attention

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Goal. Feature-based attention (FBA) modulates the perceptual space with both a monotonic profile (i.e., feature-similarity gain) and a non-monotonic profile (i.e., surround suppression). An important question is whether the profile of attentional modulation is a fixed property of attention system or is adaptable to task demands. We hypothesized that the attentional profile depends on perceptual contexts to ensure efficient processing. Here, we explored this hypothesis by manipulating levels of feature competition between a target and distractors. Methods. In the primary task, participants viewed a rapid serial visual representation (RSVP) of multiple stimuli at the center of the screen, which consisted of orientation-filtered Gaussian noise. The target was filtered around a narrow band in a random orientation (bandwidth: ±5°), while the masks contained a range of orientations that were either close to the target (±5° to ±45°) – the high competition condition, or away from the target (±50° to ±90°) – the low competition condition. We manipulated FBA through an orientation precue before the central RSVP and instructed participants to detect the cued target. Meanwhile, we employed a secondary task in which participants monitored two peripheral gratings on both sides of the center RSVP stream for a brief contrast decrement in one of the gratings. We systematically sampled the gratings' orientations away from the cued orientation and used performances in the secondary task to measure the attentional profile. Results. Performances in the primary task were well equated between high and low competition conditions. For the secondary task, we only found a non-monotonic surround suppression profile in the high competition condition, but not in the low competition condition, which suggests a flexible deployment of different attentional profiles. Therefore, the surround suppression mechanism may be deployed to effectively isolate the target orientation when the task requires resolving a high degree of perceptual competition.

Face Perception 2

Poster Session B > Face Perception 2 > Poster B121

Radial biases influence face identification in the periphery

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In peripheral vision, humans have a better sensitivity to radial orientations (pointing towards the fovea) than to tangential ones (orthogonal to the fovea). We reasoned that due to these radial biases, objects perceived in peripheral vision may be encoded as if they were 'filtered' in the radial direction. Following this reasoning, humans should be better at identifying the face of their conspecifics along the horizontal meridian. These locations would facilitate the encoding of horizontal orientation, which is known to convey the most useful information for the recognition of face identity in foveal vision. To test this hypothesis, we instructed participants to recognize upright and inverted faces appearing briefly either at the fovea, or at 8° of eccentricity along the horizontal or vertical meridian. We measured face recognition as a function of stimulus visibility by parametrically scrambling stimulus phase. We then compared the psychometric functions for upright and inverted faces. A shift between the two functions, i.e. the face inversion effect, was taken here as a marker of the 'specificity' of face identity processing. We found a significant inversion effect along the horizontal meridian. This effect was comparable to that of the fovea, suggesting the engagement of face-specialized mechanisms at both locations. However, the inversion effect strongly reduced in magnitude when faces were presented on the vertical meridian, suggesting that the face processing system was disrupted through the reduction in the horizontal information most diagnostic to identity encoding. This result supports the hypothesis that radial biases in peripheral vision modulate the encoding of face identity cues by limiting access to oriented content.

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Untangling human face identity based on horizontal information

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Why does human face identification mainly rely on the processing of the horizontally oriented cues? Is it because the face image contains most of its contrast in this range, and more particularly at the level of the eyebrows, eyes and mouth, features known to be crucial for face recognition? Alternatively, could the horizontal range of face information provide cues to identity that are more resistant to the drastic variations in face appearance resulting from e.g. changes in viewpoint? To disentangle these accounts, twenty-two human observers performed an identity recognition task with face stimuli presented one by one under different viewpoints (from full-front to profile views), and filtered to preserve contrast in selective orientation ranges. We found that the gaussian-shaped function relating the sensitivity to face identity to orientation peaked around the horizontal angle irrespective of viewpoint. A model observer performed a similar task by comparing each stimulus (pixel-wise) to the set of face images in different orientation ranges, within each viewpoint. Its performance suggests that image identity cues shift away from horizontal as viewpoint aversion increases. A second model observer performed the same task by comparing face images in selective orientation ranges, but across viewpoints. The performance of this model observer kept sharply tuned to the horizontal range, no matter the viewpoint of the stimulus. This result supports the notion that the horizontal orientation range of the face image conveys cues to identity that are more stable across viewpoint variations. The comparison of model and human performance suggests that human face identification tunes to horizontal orientation because this range conveys the richest feature cues in full-front views while it provides the most stable identity cues when moving away from full-front. These results yield novel insight on the strategies developed by the human visual system to achieve invariant face recognition.

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Object Categorization and Response Bias Flexibly Change Depending on Cross-Spatial Scale Coherence and Task Demands

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Categorization of visual stimuli at different levels of abstraction relies on the encoding of relevant diagnostic features present at different spatial scales. We used the Eidolon Factory (Koenderink et al., 2017), an image-manipulation algorithm based on the scale-space representation of the early visual cortex that introduces random disarray fields across spatial scales. When the disarray is incoherent, edges become fuzzy and less defined; when it is coherent, the coarser scales dictate where the finer scales end up, leading to warping of the local structure of the image. With this method, we asked: is the brain using the global shape or is it detecting some salient feature to resolve a recognizable object? And, how is the correlational structure of different spatial scales interacting with the task demands? Images of animal faces, human faces and everyday objects were disarrayed coherently or incoherently to create a family of 50 eidolons per image with increasing disarray. Participants (N=217) viewed each family of eidolons in a smooth sequence from maximum disarray to none and performed a category verification task either at the superordinate (any face type) or basic (human face only) levels at different levels of uncertainty. In the first response, they used their gut feeling to respond, for the second response they had to be sure of their decision. When participants used their gut feeling to respond, we observed a basic-level advantage, but not an effect of the type of disarray. When they were sure of their response, we observed a superordinate advantage and stronger disarray effects in the coherent stimulus. Furthermore, participants changed their decision criterion depending on the abstraction level of the task. These results suggest that the visual system flexibly adjusts the relevant perceptual information depending on task context and that it does not strictly adhere to feedforward processing.

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The role of the eye region for familiar face recognition: Event-related brain potentials reveal repetition priming for blur chimeras but not fully filtered faces.

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Previous studies have shown that the detrimental effect of negative contrast information on familiar face recognition is largely eliminated by retaining a contrast positive eye-region, creating so-called 'contrast chimeras' (Gilad et al., 2009). Event-related brain potentials, however, revealed that contrast chimeras elicit an enhanced N170, suggesting inefficient face detection, and no repetition priming in the N250r (Wiese et al., 2019). This latter finding was interpreted as suggesting that contrast-positive eyes, when presented in an otherwise negative face, are insufficient to activate representations relevant for recognition. Alternatively, however, this absent N250r might reflect a knock-on effect from disrupted face detection at the earlier N170 stage, interfering with subsequent stages of identity recognition. Here, we created 'blur chimeras', with face regions except for the eyes spatially low-pass filtered at six cycles/image. We hypothesized that this would reduce accessibility to detailed recognition-relevant information, while retaining typical face detection efficiency. Participants were presented with 240 prime/target pairs of celebrity faces, either unfiltered, fully blurred, or as blur chimeras. In half of the pairs, identity was repeated, while the other half consisted of non-repetitions. Unfiltered pairs provided a typical prime N170, and an N250r indicating clear identity repetition priming. Moreover, unlike fully blurred faces, blur chimeras elicited a similar N170 to unfiltered faces. Crucially, blur chimeras but not fully blurred faces elicited a significant N250r, demonstrating identity repetition priming. Compared to unfiltered faces, however, the blur chimera N250r was slightly delayed, suggesting less efficient processing. We conclude that detailed information from the eye-region in an otherwise low-pass filtered face is sufficient to activate familiar face representations, provided that the manipulation allows for typical face detection efficiency. Despite this, processing identity with detailed information only from the eye-region is inefficient, and additional facial details facilitate recognition.

Poster Session B > Face Perception 2 > Poster B125

Face categories modulate the perceived proximity of faces

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Faces are complex visual stimuli, varying on innumerable perceptual dimensions (e.g., face contour, skin tone, or bone structure). Despite the virtually infinite number of combinations of these perceptual cues, we tend to group faces based on social categories, such as race and gender. The formation of face categories represents an adaptation of perceptual systems to the environment, therefore facilitating face processing (Tanaka, 2001). Here, we investigated how the categories of race and gender modulate perceived proximity. We specifically used the Fat Face Illusion (FFI) to gauge face proximity: when two identical faces are vertically displayed, the bottom face is perceived closer, as it appears larger than the top face (FFI, Sun et al., 2012). If face categories modulate perceived proximity, we predict different FFIs between the categories. We used faces from social categories that varied in Race (Caucasian and Asian) and Gender (Female and Male). Participants saw two identical faces vertically aligned and were asked to indicate which face they found larger. To examine the generality of this effect, we tested adult participants in France (N=30), China (N=30), and Canada (N=31). The French participants were familiar with Caucasian faces, and vice versa for the Chinese participants. The Canadian participants had comparable exposure to Caucasian and Asian faces. All participants biasedly judged the bottom face as larger (83.27%, $p < .001$). Importantly, Race and Gender significantly modulated this perceptual illusion ($p < .001$): FFI was weaker for the Asian Female faces than for the other face categories, regardless of participants' previous experience with the face categories. Altogether, these cross-cultural findings indicate that social category modulates the size of the FFI. This differential effect possibly reveals universal stereotypes associated with face categories. For example, Asian females may be perceived as less threatening and more agreeable than individuals from other social categories.

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Reading direction alters how faces are perceived

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Evidence suggests that the perception of facial appearance is driven more by one side of the face than the other. A left-side bias for face perception has been shown using a chimeric face matching task, in which observers tend to judge a face composed of the two left halves of a face (the side of the face in the left visual field of the observer, here termed the LL face), to more closely resemble the original face than the RR face. This effect is thought to arise from right hemisphere specialization for faces. Here, we examined the effect of reading direction on this facial bias in a large group of subjects proficient either in English, Arabic (read from right to left) or both languages. Observers performed the chimeric face matching task whilst their eye movements were measured, and an additional group of observers performed the task online. To evaluate whether the bias was specific to the side of the face in the left visual field or the physical half of the face, the target face was presented as originally photographed and as its mirror-reversed version (on separate trials). The results confirm a left-side bias for face perception, both in choice responses and in eye movements, consistent with previous work. The bias was modulated by language proficiency: observers more proficient in Arabic than in English showed a smaller bias, which was reversed in sign in certain conditions, and their eye movements were more symmetrically distributed across the target face than English-reading observers. Unexpectedly, the bias was smaller for the mirror-reversed target faces than the original faces for all groups. We interpret the results overall as an effect of visual experience, here, habitual scanning of text, on a putatively hard-wired perceptual bias.

Acknowledgements: This work was supported by the University Research Board (URB) of the American University of Beirut

Poster Session B > Face Perception 2 > Poster B127

Tracking Face learning: Understanding face familiarity in natural and laboratory settings.

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Familiar faces are processed differently than unfamiliar faces and the time-course of the shift from unfamiliar to familiar face representation is poorly understood. In two studies we looked at face learning in the wild and in the laboratory. In Study 1, participants met one of two tutors (target identities) during a semester. To test participants' face learning, we administered a novel person-specific matching task (deciding whether two images, presented simultaneously, show the same person or two different people) at five time points. The results showed an improvement in accuracy following 10 minutes of interaction with a target identity, relative to the control identity. This effect was larger for matched than mismatched trials and further increased a week later (at time point three), despite no additional contact with the target, suggesting memory consolidation. In Study 2, we examined whether laboratory learning would improve performance on the same matching task used to test participants in Study 1. To compare different types of learning we substituted the live learning for pairs of matched images, a movie clip, or a matching task with feedback for targets. The results showed no effect of the experimental familiarization, i.e., merely performing the matching task was sufficient for face learning, even in the absence of feedback. Our results suggest that an initial hallmark of face learning is the ability to identify a face as a target identity, but the ability to differentiate it from other, similar faces, develops later in time. Finally, as participants were able to learn from our matching task even without feedback, a new, highly sensitive and identity-specific testing paradigm is needed to fully understand the time-course of face learning in the wild.

Acknowledgements: EPSCR

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Confidence judgements for detecting and discriminating changes in emotional facial expressions

View Poster | Play Video | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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The ability to reflect on our own performance when we have to judge subtle changes in facial expressions might have a strong influence on our future social communication. It is still unknown to what extent introspection can access the accuracy of these judgements. Here, we aimed to investigate how confidence judgments map onto performance for

detecting and discriminating emotional facial expressions. We sequentially presented two faces with the same identity, but with two different morphed levels of intensity of the same emotional expression, one corresponding to a nominal 'pedestal' intensity (0% for detection, or 75% for discrimination), and the other corresponding to the pedestal plus one of seven intensity increments. At the end of each trial, we asked 98 participants to report an intensity judgement ('which face had the stronger expression intensity?') and also a confidence judgement ('how confident are you that your intensity judgement was correct?'). On average, intensity thresholds (our performance measure) for detection and discrimination did not differ, corresponding to about 18% intensity increment. However, the psychometric function was shallower for discrimination, implying that participants could discriminate subtle intensity increments better than they could detect them. Confidence judgements revealed that participants hugely overestimated their ability to perceive small intensity increments, for which their performance was in fact at chance. This overconfidence was more pronounced for intensity discrimination than for detection, probably because, in the former, but not in the latter condition, the pedestal reduces uncertainty about which expression is being presented on a given trial. Moreover, the difference between confidence and performance thresholds correlated negatively with performance thresholds, indicating that poor performers were more aware of how they performed than good performers. This is the opposite pattern of results to that observed in the 'Dunning-Kruger' effect and it might extend to other domains of sensory discrimination.

Acknowledgements: We would like to acknowledge the support of the Wellcome Trust to this research (individual fellowship to A.B., Award ref: 213616/Z/18/Z).

Poster Session B > Face Perception 2 > Poster B129

Happy centre, happy whole: Foveal vision determines the perceived emotion of face ensembles

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In ensemble perception, the visual system extracts summary statistical information of multiple items. Ensemble perception occurs for low-level features such as orientation, as well as higher level features such as facial expressions. The different contributions of foveal and parafoveal vision to the extraction of average facial expressions are still under debate. In two experiments, groups of faces with varying emotions (11 levels of morphed expressions from happy to disgusted) were presented for 100ms at three different eccentricities (0°, 3°, 8°). Observers reported the perceived emotion (responding "positive" or "negative") of either only the central face (central task) or the average of all faces (average task). In both tasks, stimuli consisted of a central face flanked by 8 faces. Additional stimuli consisted of a single face (central task) and a set without central face (average task). In Experiment 1, flanker emotions were uniform, in Experiment 2 they were varied. As expected, performance in the central task declined with increasing eccentricity in all conditions. Reporting the average emotion, however, was superior when stimuli were presented at 3° compared to 0° and 8°. Importantly, at 0°, the perceived average emotion was strongly biased by the central face. When the central face was absent, performance was best at 0° (with flankers surrounding the fixated region). The central face bias was also evident when comparing congruent trials, where central and flanker emotions were both either positive or negative, with incongruent trials. Performance was better when central face and flankers were congruent compared to incongruent. Our results showed how foveal input determined the perceived emotion of ensembles of faces, suggesting that ensemble perception may fail when salient target information is available in central vision.

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Facial expressions of emotion include iconic signals of rejection and acceptance

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What are the evolutionary origins of facial expressions? One theory posits that they evolved from facial movements that control sensory stimulation (e.g., closing eyes to reduce visual input). Such signals would afford a salient iconicity that

could facilitate communication. Here, we examined whether facial expressions of emotion include expansion and contraction facial movements that serve as icons of rejection and acceptance. Using the data-driven method of reverse correlation, we first modelled dynamic facial expressions of the six classic emotions – happy, surprise, fear, disgust, anger and sad – in each of 60 participants (Western, 31 females). On each of 2400 experimental trials, participants categorized a facial animation comprising a randomly activated subset of individual facial movements (Action Units; AUs) according to the six classic emotions or 'other.' We then modelled the dynamic AUs associated with each participant's emotion response using non-parametric permutation inference ($p < 0.05$), resulting in 360 dynamic facial expression models (60 participants X 6 emotions). Next, we identified in each facial expression model, iconic facial movements and found that expansion movements – e.g., brow raising (AU1-2), eye opening (AU5), nostril dilating (AU38) and mouth gaping (AU26) – are primarily associated with acceptance messages (e.g., happy, surprise). Contraction movements – e.g., brow lowering (AU4), wincing (AU7), nose wrinkling (AU9), lip pinching (AU23) – are primarily associated with rejection messages (e.g., fear, disgust, anger, sad). Finally, we replicated these results with a separate set of facial expressions of conversational messages – thinking, interested, bored and confused (20 Westerners, 10 females). Together, our results show that facial expressions comprise latent iconic facial signals that represent rejection or acceptance in line with their social function. Future research will address how this iconicity could be exapted to ground more complex and abstract meanings in multimodal face-to-face communication.

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Social Trait Facial Expressions Comprise Latent Affective Facial Signals

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Theories of social perception posit that the perception of social traits from faces, such as trustworthiness and dominance, are overgeneralizations of emotions (e.g., Montepare & Dobish, 2003), suggesting a latent affective signaling structure. Here, we address this question using a data-driven approach to model dynamic facial expressions of four key social traits – trustworthiness, warmth, dominance, and competence – and six classic emotions – happiness, surprise, fear, disgust, anger and sadness – and compared their face movement patterns. On each experimental trial, we generated a random facial animation comprised of a random sub-set of individual dynamic face movements (Action Units, AUs; Ekman & Friesen, 1978; see Yu et al., 2012 for details). Sixty participants (white Western, 31 women; mean age = 22+/-1.71 years) each categorized 2,400 such facial animations (sex-balanced, same-ethnicity) according to the six emotions (see Jack et al., 2014). A separate participant group (five white Western, 3 females, mean age = 24.0+/-5.2 years) also rated 2,400 facial animations on each of four social traits on a 7-point scale, e.g., 'extremely dominant' to 'extremely submissive' in separate tasks. We then built per-participant dynamic facial expression models of each emotion and social trait by measuring the statistical relationship between the face movements on each trial and the participants' responses using Monte Carlo simulations and a one-tailed test ($p < .05$). Analysis of the resulting facial expression models revealed systematic commonalities between social traits and emotions in line with the overgeneralization hypothesis. Specifically, positive social traits such as trustworthiness and warmth, share Lip Corner Puller with positive emotions such as happiness. Negative social traits such as dominance share Nose Wrinkler and Upper Lip Raiser with negative emotions such as anger and disgust. Our results enhance understanding of social face perception by revealing the latent expressive patterns across social traits and emotions.

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Poster Session B > Face Perception 2 > Poster B132

The influence of emotion and empathy on gaze patterns when exploring controlled static and ecological dynamic faces

View Poster | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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The influence of facial emotions on gaze patterns when exploring faces is still debated. Previous research reported that the relative proportion of fixations on the different face areas is (Eisenbarth & Alpers, 2011; Schurgin et al., 2014) or is not (Blais et al., 2017, de Boer et al., 2020) modulated by the expression processed. While most previous studies used static face images or simulated dynamic facial expressions (Blais et al., 2017), we propose to test how these findings generalize to more ecological spontaneous dynamic expressions of emotion. We recorded the eye movements of 170 participants with different empathy profiles, while categorizing the valence of static and dynamic emotional faces. Static emotions were performed by actors from the classic Karolinska Directed Emotional Faces database (KDEF, Lundqvist et al., 1998), while dynamic emotions were genuine natural facial expressions from ordinary people, filmed in natural but standardized conditions (DynEmo database, Tcherkassof et al., 2013). We found strong similarities between the gaze patterns in static and dynamic conditions. We found a main effect of emotion on fixation rate on all facial regions of interest (left and right eye, nasion, nose, mouth, rest of the face). In both conditions, we only found an effect of empathy on fixation rate on the left eye, which was less fixated when the observer had less empathy. We did not find any effect of gender on fixation rates. Our results suggest that moderate differences in gaze behavior like the ones associated with the observer's empathy profile can generalize from a classic and well controlled static dataset, to a more ecological and dynamic dataset.

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The Impact of Acute Diesel Exhaust Exposure on Executive Brain Function

View Poster | Play Video | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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Research suggests that human brain health is harmed by chronic exposure to neurotoxic atmospheric pollutants, probably as a result of neuroinflammatory responses. Previous studies correlated chronic air pollution exposure to children's neurodevelopment and to neurodegeneration in the elderly, without using explicit, focussed cognitive tasks. Although vaccination studies show that acute inflammation can impact attention and social cognition a few hours after vaccination, whether exposure to air pollution could cause similar cognitive dysfunction is unknown. Using an atmospheric chamber, we exposed 81 young healthy adults to diluted diesel exhaust (or clean air) for one hour before completing a facial identification task either immediately or after a four-hour delay period. In the face task, participants made speeded identifications of the gender of a briefly presented target face in the presence of simultaneously presented distractor face (2-face trials) or a scrambled image distractor (1-face trial). Response times (RT) for 2-face trials preceded by a 2-face trial (repeat sequences) versus a 1-face trial (non-repeat sequence) were compared to index reactive attention. Poor control over reactive attention is associated with large differences is such tasks. A significant interaction between sequence type and pollution group was identified, such that reactive attention (non-repeat minus repeated sequences) was 22ms greater for the delayed-diesel compared to the delayed-clean air group, indicating that the former had less efficient adaptive cognitive control. Reactive attention was unaffected by diesel exposure when tested immediately after exposure; response accuracy was similar for all groups arguing against the possibility that speed-accuracy trade-offs could explain the results. These findings provide the first direct experimental evidence that short, city street comparable (8.89µg/m3 PM2.5; 206ppb NO2) diesel exposure can negatively impact attentional executive functioning several hours later. Finding delayed rather than immediate effects support the possibility that such effects stem from neuroimmune, rather than respiratory, responses.

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Synthetic faces: how perceptually convincing are they?

View Poster | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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Recent advances in machine learning, specifically generative adversarial networks (GANs), have made it possible to synthesize highly photo-realistic faces. Such synthetic faces have been used in the creation of fraudulent social media accounts, including the creation of a fictional candidate for U.S. Congress. It has been shown that deep neural networks can be trained to discriminate between real and synthesized faces; it remains unknown, however, if humans can. We examined people's ability to discriminate between synthetic and real faces. We selected 400 faces synthesized using the state of the art StyleGAN2, further ensuring diversity across gender, age, and race. A convolutional neural network descriptor was used to extract a low-dimensional, perceptually meaningful, representation of each face. For each of the 400 synthesized faces, this representation was used to find the most similar real faces in the Flickr-Faces-HQ (FFHQ) dataset. From these, we manually selected a matching face that did not contain additional discriminative cues (e.g., complex background, other people in the scene). Participants (N=315) were recruited from Mechanical Turk and given a brief tutorial consisting of examples of synthesized and real faces. Each participant then saw 128 trials, each consisting of a single face, either synthesized or real, and had unlimited time to classify the face accordingly. Although unknown to the participant, half of the faces were real and half were synthesized. Across the 128 trials, faces were equally balanced in terms of gender and race. Average performance was close to chance with no response bias (d-prime = -0.09; beta = 0.99). These results suggest that StyleGAN2 can successfully synthesize faces that are realistic enough to fool naive observers. We are examining whether a more detailed training session, raising participants' awareness of some common synthesis artifacts, will improve their ability to detect synthetic faces.

Object Recognition: Dynamics

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Brain networks dynamically represent and transfer behaviorally-relevant face and object features but quickly reduce them when they are behaviorally-irrelevant

View Poster | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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To categorize visual inputs, brain networks selectively attend to, represent and transfer stimulus features that are behaviorally relevant, and likely reduce those that are not. Where, when and how these information processes happen remains largely unknown, in part because the specific face, object or scene feature that the brain (and Deep) networks process for task behavior remain themselves unknown, disabling information processing accounts. Here, we demonstrate that brain networks dynamically represent and transfer face and object features when they are relevant for task-behavior, but reduce them when they are not. Ten participants each applied four categorization tasks (in different sessions) to the same stimulus set, to isolate task effects on face and object features and control likely low-level confounds (e.g. when contrasting images of face vs. object). Each 2 AFC task involved the same pictures of a realistic, typical city scene comprising varying targets: a centrally positioned face (male vs. female; happy vs. neutral), left flanked by a pedestrian (male or female), right flanked by a parked vehicle (car vs. SUV). Each trial started with image pixels randomly sampled with Bubbles, that each participant categorized while we recorded their MEG activity (on 12,773 voxels) and behavior. Independently for each participant (9 replications), information theoretic quantities revealed (1) the image features relevant for each categorization task, (2) their representation and transfer (post ~120 ms) from occipital cortex into the ventral and parietal pathways when they are relevant for behavior (e.g. parked vehicle in car vs. SUV) but (3) their rapid (before 170 ms) reduction in occipital cortex when they are task-irrelevant (e.g. parked vehicle in male vs. female face). This approach psychophysically grounded into the processing of behaviorally relevant information better realizes the elusive promise of neuroimaging by providing novel insights into the information processing algorithms of the brain.

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Poster Session B > Object Recognition: Dynamics > Poster B136

Can MEG Source Localization Reveal the Time Course of Processing in the FFA, PPA, and EBA?

View Poster | Play Video | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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fMRI has provided a rich spatial map of category-selective responses across the ventral visual cortex, and EEG/MEG can inform the precise time course of visual processing. But what we really need is both temporal and spatial precision simultaneously. Can MEG source localization reveal the time course of processing in specific functional regions, distinguishing them from nearby regions? Here we addressed that question by collecting both MEG and fMRI responses from the same fifteen participants to the same images of faces, bodies, scenes, and objects. We used fMRI localizers to define the FFA, PPA, and EBA in each participant individually. We then computed source estimates from the MEG data using dynamic statistical parametric mapping, extracting the time courses of estimated MEG source amplitudes to each stimulus category within each fMRI-derived ROI. Source-localized MEG data showed a selective response to bodies peaking at about 160 ms in bilateral EBA that was not present in the FFA or PPA. A highly prominent right-lateralized face response peaking around 130 ms was detected in all three fROIs, while no clear peak response to scenes was present in any fROI. Analyses of source-localized responses across the whole cortex revealed a similar picture, with scene-selective responses spatially blurred across the occipital cortex, right-lateralized face-selective responses spanning much of the ventral surface of the cortex (extending well beyond the fusiform gyrus), and body-selective responses arising later on the lateral surface of both hemispheres in the vicinity of the EBA. These results suggest that right-lateralized face processing peaks on the ventral surface of the brain around 130 ms and body-selective processing on the lateral surface around 160 ms. However, they also indicate that MEG source localization is unable to detect fMRI-expected signals from some regions (PPA) or to precisely localize signals to the spatial grain of fMRI-defined functional regions.

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Contributions of the early visual system to high-level visual distinctions

View Poster | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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Because the complexity of visual features for which neurons are tuned increases from early to late stages of the ventral visual stream, the working hypothesis is that object recognition, categorization, and novelty/memory perception are primarily mediated by higher visual areas. However, observers can categorize images as objects or animals or as big or small even when the images have been filtered to preserve some low-level features but are rendered unidentifiable (‘texforms’, Long, Chen & Konkle, 2018). This observation implies that even early visual cortex, in which neurons respond to simple stimulus features, may encode signals that are of use in seemingly high-level visual functions. We tested this hypothesis by recording from populations of neurons in early and mid-level visual cortical areas while rhesus monkeys viewed texforms and their unaltered source stimuli (simultaneous recordings from areas V1 and V4 in one animal and from V4 in a second). Using recordings from a few dozen neurons, we could decode the size and animacy of both original images and texforms. We also observed repetition suppression (reduced responses to familiar rather than novel stimuli) to both stimulus categories, even when the second presentation of a stimulus occurred tens of seconds after the first presentation with multiple other stimuli and eye movements in between. We compared category encoding and repetition suppression to the ability of human observers to identify and categorize the texforms that originated from different stimuli, and found that the humans’ categorization performance is related to the ability to decode size and animacy from V1 and V4. Our results demonstrate that neuronal populations early in the visual hierarchy contain signals useful for higher-level object perception and memory, and suggest that these responses to simple stimulus features show preliminary untangling of higher-level distinctions.

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Dynamic representation of information prediction in the brain

View Poster | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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Since Helmholtz, the human brain supposedly predicts upcoming information for subsequent processing. However, tracing the dynamics of a predicted information content remains challenging in neuroimaging. Here, we do so with predictions of the Spatial Frequency (SF) contents of Gabor patches. On each experimental trial, seven observers categorized the LSF vs. HSF of Gabor patches displayed in the left or right visual fields, at an eccentricity ensuring their initial contra-lateral hemispheric projections, while we concurrently measured each observer's single trial source-reconstructed MEG activity on 12,773 voxels. In a two-stage cueing design, a first visual cue (left vs. right dot) predicted the location (left vs. right) of the incoming Gabor patch, followed by an auditory cue (a sweeping tone at 220 Hz vs. 1760 Hz) that predicted the upcoming SF contents (LSF vs. LSF) (and vs. 880Hz for an invalid cue), followed by the Gabor patch itself. As expected, valid cues reduced behavioral reaction times in all observers. We traced the dynamics of LSF vs. HSF prediction following auditory cue onset, when the Gabor location is known. Every 2 ms post stimuli, we computed the mutual information between LSF vs. HSF cues and the corresponding responses of each. voxel (N = 12,2773), separating left- and right-predicted trials. Prediction representation (i.e. LSF vs. HSF) started in auditory cortex (superior temporal gyrus, ~80ms post-cue), then frontal cortex (~100ms) then early visual cortex (~120 ms post-cue and ~1100ms prior to Gabor onset). Furthermore, MEG activity of auditory cortex and early visual cortex redundantly represented the SF prediction, separately for left and right trials, indicating they represent the same predicted contents on individual trials. In sum, our results show where, when and how predicted SF Gabor contents dynamically propagate from auditory to visual cortices, before stimulus onset, to speed up subsequent perceptual decision behavior.

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From the lab into the wild: studying cognition with mobile EEG and augmented reality

View Poster | Play Video | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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Our visual environment impacts multiple aspects of cognition including perception, memory and attention. However, to understand the neural underpinnings of cognition, studies traditionally remove or control the external environment. As a result, we have limited understanding of neurocognitive processes beyond the lab. Here, in order to bridge the gap between studying cognition in the classic lab setting and in the real world environment, we used mobile EEG (mEEG) and augmented reality (AR) that allows to maintain some control over perception by placing virtual objects into the real world. In this research, we aimed to validate our AR and mEEG setup using a well-characterised cognitive response - the face inversion effect. Participants viewed upright and inverted faces in three settings (1) lab-based, (2) walking through an indoor environment while seeing photos of faces, and (3) walking through an indoor environment while seeing virtual faces. Results show greater low frequency activity for inverted compared to upright faces in all experimental settings, demonstrating that cognitively relevant signals can be extracted from mEEG and AR paradigms. Further, we present a potential route to explore the link between dynamic environments and EEG. Low and mid-level visual features were extracted from head-mounted videos recorded while walking through an outdoor environment using a computational model of visual cortex, before statistically relating the features to continuous EEG. As expected, we find that posterior electrodes correlated with video features, highlighting a framework to relate continuous perceptions to continuous neural activity. Together, this research helps pave the way to exploring neurocognitive processes in real

world environments.

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Poster Session B > Object Recognition: Dynamics > Poster B140

Modeling feedback representations in ventral visual cortex using a generative adversarial autoencoder

View Poster | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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In less than the blink of an eye, the human brain processes visual sensory input, interprets the visual scene, identifies faces, and recognizes objects. Decades of neurophysiological studies have demonstrated that the brain accomplishes these complicated tasks through a dense network of feedforward and feedback neural processes in the ventral visual cortex. So far, these visual processes are primarily modeled with feedforward hierarchical neural networks, and the computational role of feedback processes is poorly understood. In this study, we developed a generative autoencoder neural network model and adversarially trained it on a large categorically diverse data set of images (Objects, scenes, faces, and animates). We hypothesized that the feedback processes in the ventral visual pathway can be represented by reconstruction of the visual information performed by the generative model. To test the hypothesis, we compared representational similarity of the activity patterns in the internal layers of the proposed model with magnetoencephalography (MEG) and functional magnetic resonance imaging (fMRI) data acquired while participants (N=15) viewed a set of 156 images organized in four categories of objects, scenes, faces, and animates. Our proposed model identified two segregated neural dynamics in the ventral visual pathway. The representational comparison with MEG data revealed a temporal hierarchy of processes transforming low level visual information into high level semantics in the feedforward sweep, and a temporally subsequent dynamics of inverse processes reconstructing low level visual information from a high level latent representation in the feedback sweep. Further, representational comparison of model encoder and decoder layers with two fMRI regions of interests, namely early visual cortex (EVC) and inferior temporal area (IT), revealed a growing categorical representation (similar to IT) along the encoder layers (feedforward sweep) and a progression in detail visual representations (akin to EVC) along the decoder layers (feedback sweep).

Acknowledgements: We would like to thank Western BrainsCAN for the generous support of this research. Computational modeling was conducted on Compute Canada resources.

Poster Session B > Object Recognition: Dynamics > Poster B141

The dynamic relationship between neural category discrimination and perceptual behavior measured with iEEG across tasks

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Regions of ventral temporal cortex (VTC) demonstrate category selective responses that when disrupted lead to perceptual deficits affecting the category that area is selective for. However, the relationship between dynamic category selective activity in VTC and perceptual behavior is unclear. To investigate this relationship, intracranial EEG data was collected from 32 participants while they completed a 1-back category localizer task containing pictures of faces, words, bodies, hammers, houses, and phase-scrambled objects. Participants were asked to press a button if any image was repeated twice in a row (exemplar level repeat detection). Multivariate classifiers were trained on non-repeat image trials to predict which category the participant viewed during repeat trials. Then the relationship between the confidence of these category classifiers and behavior was examined. Around peak category selectivity (50-250 ms post-stimulus presentation) lower classifier confidence was associated with faster reaction times (RT) on repeat trials. This suggests that greater repetition suppression of peak category selective activity facilitates perceptual behavior during the 1-back task. Conversely, higher classifier confidence was associated with faster RT around the time of response (500-750 ms),

suggesting that greater category information around this time facilitates perceptual behavior. We then applied these category classifiers to data from a gender discrimination task to determine if these relationships generalized. Greater face category confidence from 500-750 ms was associated with faster RT like during the 1-back task; however, there was no relationship between classifier confidence and behavior around peak face selectivity (50-250 ms). These results suggest that perceptual behaviors have a task general relationship with category selective VTC activity around the time of response and a task specific relationship around the time of peak VTC selectivity. Future work is necessary to determine the local and network-level neural features that give rise to dynamic category selective responses that are related to perceptual behavior.

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Poster Session B > Object Recognition: Dynamics > Poster B142

Modelling local and global explanations for shape aftereffects with naturalistic novel stimuli

View Poster | Play Video | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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A widely-used psychophysical tool for inferring visual mechanisms is adaptation. Perceptual distortions known as aftereffects arise following extended visual exposure to a stimulus, including complex patterns and shapes. Some researchers have argued that shape aftereffects reveal adaptation of mechanisms sensitive to global shape properties, while others propose they can be explained by localized adaptation to simpler properties such as tilt. Here, we investigate methods to tease these hypotheses apart. Most previous works used simpler and/or familiar forms (e.g., radial frequency patterns, geometric shapes, faces). Here we use complex but naturalistic shapes synthesized by Generative Adversarial Networks (GANs) trained on >25,000 animal silhouettes. Drawing samples from the GAN's latent space allows us to synthesize novel 2D shapes that transition smoothly between one another, and are complex yet systematically related. Observers adapted to individual shapes from this generative shape space, then judged the appearance of nearby shapes in a two-alternative forced-choice task. Their responses demonstrated robust and systematic perceptual distortions of shape using such stimuli. Indeed, a given shape could predictably be made to look like specific other shapes depending on which adaptor stimulus was used. To tease apart the relative role of local vs. global adaptation, we simulated the effects of two variants of tilt and positional aftereffects: the local model assumes aftereffects exaggerate differences between test and adaptor within localized image regions, while the global model assumes such distortions exaggerate differences between 'corresponding' parts of shapes, after completing high-level inferences regarding part-correspondence. Initial findings show that positional adaptation has a larger contribution than tilt adaptation to novel-shape aftereffects. We then show how to use the generative shape networks to synthesize tailored shape sets that can tease apart the predictions of local vs global models of adaptation. Our findings provide new methods for probing and modeling adaptation to complex visual stimuli.

Acknowledgements: This research was funded by the DFG funded Collaborative Research Center "Cardinal Mechanisms of Perception" (SFB-TRR 135) and the ERC Consolidator award ''SHAPE'' (ERC-CoG-2015-682859).

Poster Session B > Object Recognition: Dynamics > Poster B143

Individual differences in attractive and repulsive context effects on shape categorization

View Poster | Play Video | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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How we perceive a visual form not only depends on the currently presented shape, but also on the temporal context in which it is shown. Earlier research found both attractive and repulsive context effects in perception. Tendencies to see

the current stimulus similar to how the previous stimulus was seen (i.e., hysteresis, attraction) co-exist with tendencies that repel the current percept away from the organization for which there was most evidence in the previous stimulus (i.e., adaptation, repulsion). While previous research focused on group-level effects of temporal context, this study investigated whether everyone shows effects of the previous percept and the previous stimulus in the expected direction, and whether possible individual differences in these attractive and repulsive temporal context effects are consistent. Participants (N=209) conducted a perceptual categorization task with two series of abstract morph figures as stimuli, for which average temporal context effects were identified before. A Bayesian multilevel logistic regression analysis on the current percept was conducted to get estimates for the size of the hysteresis and adaptation effect per participant. Results indicate that almost everyone showed an attractive effect of what was perceived in the previous trial, while a repulsive effect of the previously shown stimulus was less universal. The size of the individual hysteresis and adaptation effects were strongly correlated: participants with a more outspoken attractive effect of the previous percept also showed a stronger repulsive effect of the previous stimulus. Furthermore, individual differences in the strength of the adaptation effect were heavily correlated with individual differences in the sensitivity to perceptual differences between the different morph levels. The study provides evidence for different percepts in different individuals even when presented with the same stimulus in the same context and thereby increases insight in how different individuals differentially combine previous and current input in their perception.

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Poster Session B > Object Recognition: Dynamics > Poster B144

Visual affects: Linking curiosity, Aha-Erlebnis, and memory through information gain

View Poster | Play Video | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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Current theories in curiosity research propose that our sense of curiosity is determined by the learning progress, or information gain, that our cognitive system expects to make. However, few studies have explicitly tried to quantify subjective information gain and link it to measures of curiosity. Here, we asked people to report their curiosity about the intrinsically engaging perceptual ‘puzzles’ known as Mooney images, and to report the strength of their aha experience upon revealing the solution image (curiosity relief). We also asked our participants (N = 279) to make a guess concerning the solution of the image, and we used the distribution of these guesses to compute the crowdsourced semantic entropy (or ambiguity) of the images, as a measure of the potential for information gain. We did this by computing the Shannon entropy of the probability distribution of different guesses across the total number of guesses. For example, an image with many different guess labels across participants will have a high semantic entropy, while an image with the same guess label across all participants would have low semantic entropy. Our results confirm that this semantic information gain measure is substantially associated with curiosity ($r = 0.38$, $p < .001$) and, even more so, with the aha experience ($r = .55$, $p < .001$). These findings support the expected information gain theory of curiosity and suggest that the aha experience, or intrinsic reward, is driven by the actual information gain. In an unannounced memory task after the main experiment, we also established that the often reported influence of curiosity on memory is fully mediated by the aha experience or curiosity relief ($B = .01$, $p < .001$). Our results have implications for the burgeoning fields of curiosity and psychoaesthetics.

Eye Movements: Saccades, cognition, neural mechanisms

Poster Session B > Eye Movements: Saccades, cognition, neural mechanisms > Poster B145

Eye and hand tracking during a complex task: Parsing a neuropsychological test in their subcomponents

View Poster | Play Video | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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One of the most used neuropsychological tests is the Trail Making Test (TMT). It is widely used for the diagnosis of executive dysfunctions in a wide range of clinical conditions. It has two parts, in which participants must connect several consecutive numbers (TMT-A) or both numbers and letters in alternating order (TMT-B; 1-A-2-B, etc.). TMT is a complex task and involves distinct stages supported by different executive functions. It is usually done with paper-and-pencil and only the total time is quantified, which does not allow for a detailed analysis. We designed a digital version of the TMT, where hand and eye positions were simultaneously measured. This opens a window to study the different components of the task. We showed that the overall performance was similar to the traditional version, and that it correlated with a general executive functions assessment. Moreover, the eye movements were similar in both parts, but there were fewer fixations in A, which is compatible with its faster resolution. In particular, this decrease was found in the initial exploration and planning phases during the task. Accordingly, it was observed a longer latency of the outgoing hand movements in B, which was not present in the eye movements. Finally, the number of items stored throughout the trial correlated with the performance in the task. In order to access a larger and more varied sample, we also designed a browser-based version of the TMT that recorded continuous hand movements. Preliminary results showed that the online assessment presented a similar performance compared to the paper-and-pencil version in a subset of participants. These results pave the way for a detailed analysis of complex tasks used for clinical evaluations, providing a deeper understanding of the processes underlying the resolution of traditional tests and, in particular, the implications on the executive functions assessments.

Poster Session B > Eye Movements: Saccades, cognition, neural mechanisms > Poster B146

Microsaccades before response initiation reflect angular errors in a manual peripheral localization task

View Poster | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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Microsaccade characteristics are associated with covert shifts of attention and response preparation, and therefore may carry fine directional information about upcoming errors. We tested whether microsaccades reflect angular errors in a localization task, after target appearance, but prior to manual response initiation. While maintaining central fixation, observers reported the locations of static noise patches within a Gaussian contrast envelope, at one of 12 angular locations at 7º eccentricity. Targets were presented for 50 ms, and following a 500 ms delay period, observers reported the target’s location by manually adjusting a cursor constrained at the same eccentricity as the targets. Microsaccade rate decreased near the time of stimulus onset and increased after approximately 200 ms. Microsaccades were analyzed from the delay period, 200-500 ms following stimulus offset, prior to initiation of observers’ manual response. On each trial, observers’ response errors were recorded as the angular difference between the physical location of the patch and the cursor. For targets that were within 90º of the microsaccade direction, errors in observers’ future responses were correlated with the angular difference between the microsaccade and the target location ($r = 0.31$; $p < .01$). Observers’ angular response errors were, on average, 1.14º clockwise (0.14 d.v.a) when microsaccades were clockwise relative to the target location, and 2.94º counterclockwise (0.36 d.v.a.) when microsaccades were counterclockwise relative to target location. Permutation tests indicated that these effects were trial-specific, and not an artifact of systematic angular biases in observers’ location reports across all trials. These results demonstrate that microsaccades generated between stimulus offset and non-ocular response initiation carry information about angular errors in another domain before they occur, and reveal errors related to peripheral action preparation on a more granular scale than previously shown.

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Poster Session B > Eye Movements: Saccades, cognition, neural mechanisms > Poster B147

The Dynamics of Perception and Action

View Poster | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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Issue: What are the temporal processes of visual target identification and response activation that control saccadic eye movements? And how do these processes interact? Methods: A detailed study was provided by saccade response times for visual search by two monkeys, Macacca mulatta and M. radiata. The identifiability of a singleton target and the discriminability of a Go/No-Go response cue were independently manipulated in a 2x2 factorial experiment. Both variables had large effects on the RTs and response probabilities in data collected from more than 19,000 trials for each monkey. Momentary response rates were measured by RT hazard rates at 3-4 ms intervals for each of the four conditions of singleton identifiability x response-cue discriminability. Results: Effects of the two variables were quantified at each time interval by ratios of hazard rates for the high vs low values of the variable. The influence of each variable was invariant with the value of the other variable. In each interval, response probabilities in the four conditions were accurately predicted (df = 1) as numerical products of two independent subprocesses. Conclusions: (1) At each moment, response rates in each condition were simultaneously influenced by two functionally independent subprocesses, singleton identification and response-cue discrimination. (2) Dynamics of perception and action were precisely described by their process rates (hazard rates) as functions of time. Evidently, neural processes for perception and action operated in parallel, influencing response probabilities continuously, simultaneously, and independently. RT hazard rates, rather than RTs per se, are likely behavioral correlates of the underlying neural activity.

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Poster Session B > Eye Movements: Saccades, cognition, neural mechanisms > Poster B148

Updating across saccades depends on eccentricity and predictability

View Poster | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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Humans use saccades to sample information from the world with foveal vision by fixating objects and areas of interest. The world, however, is not static, so representations of objects must be updated over time as changes occur. Foveal vision has higher acuity and reliability than peripheral vision, which is also more susceptible to phenomena such as change blindness: given this inequality, how much does peripheral vision contribute to updating object representations across sequences of saccades? Is visual awareness based on potentially outdated information at the time of object fixation, or is awareness updated based on more recent, but less reliable peripheral information? This study tested whether the representation of a rotating object was updated based on peripheral information, or whether it was based purely on the foveal view of the object, and whether the predictability of object rotation affected updating. We presented participants with four real-world objects, presented at random orientations from 360º of possible viewpoints. Participants were instructed to fixate each object in a set order, for a fixed duration. With each saccade, each object rotated either in a consecutive manner, or to a random viewpoint. Participants were then asked to make a perceptual report by rotating a randomly presented object to match the viewpoint they remembered. We correlated perceptual reports to each of the shown orientations to determine the contribution of peripheral and foveal orientations. Results showed that when objects rotated to random, non-consecutive viewpoints, participants reported the foveally-viewed orientation; however, when objects rotated in a continuous manner, participants were more likely to report more recent, peripherally-viewed orientations, depending on object eccentricity. This suggests that peripheral information is used to update perceptual representations when peripherally-viewed changes are consistent with a systematic change in the world. Peripheral information may be processed, but filtered, and only accessed under specific circumstances.

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Poster Session B > Eye Movements: Saccades, cognition, neural mechanisms > Poster B149

A sensory race between oculomotor control areas for coordinating motor timing

View Poster | Play Video | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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For successful adaptive behavior, exogenous environmental events must be sensed and reacted to as efficiently as possible. However, exogenous onsets necessarily come asynchronously to internal brain state, leading to a so-called “race condition” within visual and visual-motor areas: while there is an ongoing process trying to plan and execute a given movement, a new competing process is triggered by the exogenous event. We hypothesized that to handle such a race condition, late motor control areas in the brainstem should exhibit hallmarks of early sensory areas, in addition to their classically accepted motor functions. We recorded (in 1 monkey) from omnipause neurons (OPN’s) in the nucleus raphe interpositus (rip), constituting the very final gateway for allowing or preventing saccades. We presented stimuli of different image features (spatial frequency, contrast, orientation, and motion). OPN’s, normally tonically active and only pausing to allow saccade execution, showed robust early (<50 ms) phasic visual responses, which were also feature-tuned. Consistent with another motor structure, superior colliculus (SC), OPN’s preferred low spatial frequencies. When we directly compared OPN and SC responses, we found that OPN “visual” activity was as early as, if not earlier, than in the SC. What is the functional role of such early visual flows to such two late motor control areas? In this case, it is to control motor timing, as we confirmed with electrical microstimulation. We injected short microstimulation pulse trains to “simulate” brief phasic visual responses in either OPN’s (1 monkey), SC (2 monkeys), or V1 (1 monkey) individually. In OPN’s, visual “bursts” inhibit saccades. Contrarily, SC visual “bursts” increase saccade likelihood, and V1 visual “bursts” are consistent with sensing phosphenes. Therefore, we uncovered a sensory race between sensory and motor areas, providing a highly mechanistic description of why even simple visually-guided saccades can exhibit surprisingly large timing variability.

Poster Session B > Eye Movements: Saccades, cognition, neural mechanisms > Poster B150

Anticipatory smooth eye movements adapt to higher-order probabilistic structure of the environment

View Poster | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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Saccades and smooth pursuit eye movements are essential to visual perception and to guide many of our actions. The predictability of the environment allows not only to promptly respond to visual stimuli but also to drive anticipatory eye-movements towards the expected target location or motion direction. In two-directions motion tasks where the uncertainty about target motion direction was experimentally manipulated, several previous studies have documented anticipatory smooth eye movements (ASEM), starting ahead of target motion onset and directed in the most likely direction. Under these conditions, we previously showed that mean anticipatory eye-velocity is a linear function of direction probability. However, it is still an open question how robust and generalizable such tuning of anticipatory eye movements is with regard to more complex probabilistic manipulations of the environment. To address this question, we recorded (Eyelink1000) pursuit eye movements in healthy human volunteers while performing two novel motion tracking experiments. First, we show that ASEM can still be evoked in more complex environments, such as when the target can move in four different directions, with different probabilities for each direction. Our results indicate that anticipatory eye velocity towards the most probable direction increases linearly with its actual probability, similarly to the two-directions condition. In a second experiment with a two-segments target motion trajectory, we manipulated the probability of a 90° right/left motion turn, being conditional upon the direction (up/down) of the first target motion segment. Results demonstrate that a bias in the conditional-probability does also evoke and modulate ASEM. However, the relationship between conditional probability and ASEM is more variable across participants and may not be exactly linear. Overall, our results extend the previous results about probability-based anticipatory eye movements to more complex tasks and environmental contingencies.

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Poster Session B > Eye Movements: Saccades, cognition, neural mechanisms > Poster B151

The role of knowledge of Newtonian mechanics in anticipatory smooth pursuit eye movements

View Poster | Play Video | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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Anticipatory smooth pursuit eye movements are faster when cues to future target motion are consistent with Newtonian mechanics (Ladda et al., 2007; Badler et al., 2010; Santos & Kowler, 2017), analogous to the role of Newtonian mechanics in other visuomotor behaviors (Deeb et al., 2021). We examined the role of cues to an impending collision in a design that allowed an assessment of learning. Displays consisted of a centrally-located target and a “launcher” in a randomly chosen corner. The launcher moved toward one of two points of collision with the target. The post-collision path of the target depended on the point of collision. The direction of target motion after the collision was either consistent with (Newtonian condition) or opposite to the Newtonian prediction (non-Newtonian condition). A third (neutral) condition tested the same target paths while the launcher remained stationary. Conditions were run in separate blocks allowing equivalent opportunity for accurate prediction and learning of the target’s path on the basis of the launcher path. Pursuit in both Newtonian and non-Newtonian conditions showed anticipation. Eye velocity was higher in the Newtonian condition, and the direction of anticipatory pursuit corresponded to the direction predicted by Newtonian mechanics Anticipatory pursuit was also faster in the non-Newtonian than in the neutral condition, showing a role for learning in the absence of physically-realistic cues. The results show that both natural physical cues and learning can facilitate anticipatory pursuit. Cues that are compatible with normal physical events are more effective. Results also show that encoding of the launcher path is precise enough to allow pursuit to discriminate between two post-collision paths of the target. Future work will investigate finer discriminations and more complex paths in order to understand the limits on the representations of physical principles that are able to guide anticipatory smooth pursuit.

Poster Session B > Eye Movements: Saccades, cognition, neural mechanisms > Poster B152

Keep your eyes on the puck: Context information can induce predictive eye movements

View Poster | Play Video | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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To successfully track the puck when watching an ice hockey game the oculomotor system relies on sensory input that is lagging behind its correct position due to processing delays and motor latencies. To compensate for these delays it is necessary to make predictions about the correct position of the puck, which can get very difficult for complex movements with rapid changes in direction. We investigated whether context information (for example the player movements) contributes to these predictions by showing participants short clips of ice hockey games (10s, stationary camera) while tracking their eyes. Participants either saw the regular clip (context) or a still image of the first frame with a black dot moving along the hand-labeled puck positions (no-context). Cross-correlation analysis demonstrated that the peak correlation between eye and target movement was present with around 200 ms delay in the no-context condition, whereas the delay was significantly reduced to around 50 ms when context was available. For passes between players we observed that participants used the context information and produced predictive saccades to receiving players around 300 ms before the puck arrived. Additionally, also stopping the eye at the target location of the pass was more accurate with context, as participants significantly overshot the location of the end of the pass in the no-context condition. To gain insight into the underlying computations, we compared eye movements in the context condition to the output of a deep network model trained to use the imagery and optic flow to predict puck position. Interestingly, after partialing out the ground truth puck positions, gaze and network were still correlated, suggesting the network and the observers use similar context cues to follow the puck. Overall, our results show that the oculomotor system can efficiently use context information to counter internal processing delays by making predictions.

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Are tracking eye movements driven by an internal model of target motion ?

View Poster | Visit me in Gather.Town Egret Room on Sunday 8:00 am - 10:00 am EDT

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Tracking a moving visual target triggers a saccade which is followed by a slow eye movement whose velocity can match the target velocity only after several hours of practice. The notion of internal model has been proposed to account for this ability to foveate and maintain a moving target within the central visual field, in spite of visuomotor delays. To further investigate this hypothesis and develop potential oculomotor probes to confirm a neurophysiological substrate, we trained three macaque monkeys to track a target moving along four possible paths (one per visual quadrant) and tested the impact of two types of training on interceptive saccades toward a briefly moving target (100 ms). A first training consisted of tracking a continuously visible target (800ms). In the second training, the target was momentarily concealed 100 ms after its onset and reappeared 300 ms later. Our results show that long duration of target exposure increased the range of landing positions and times of interceptive saccades and that the first training did not change the landing of saccades toward a briefer target. During the second training, while the duration of target invisibility was gradually increased (from 100 to 300 ms) over consecutive training days, a slow eye movement (glissade) followed the interceptive saccade. After the training, the landing of interceptive saccades was changed. They were also followed by a post-saccadic glissade, but no statistically significant correlation was found between the position/time landing ratio of saccades and the post-saccadic speed. Our study shows that saccades are differently controlled depending upon the target visibility. The notion of internal model of target motion must be revisited to account for our results.

Poster Session C

Face Perception: Features and configurations

Poster Session C > Face Perception: Features and configurations > Poster C1

Revealing Visual Information Use Through Random Sampling of Spatial Frequencies and Orientations

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Face identification relies on the processing of a specific range of spatial frequencies (SF; peaks between 7 and 16 cycles per face [cpf]; e.g. Näsänen, 1999; Willenbockel et al., 2010) and orientations (SO; centered on the horizontal 90 degrees axis in Fourier space; Duncan et al., 2019). However, because SF and SO tunings are typically measured separately, how they are combined to support face identification remains unclear. Previous work compared face identification performance using limited combinations of SO (two bands: horizontal and vertical) and SF (three bands: 4, 16 and 64 cycles per image [2.66, 10,66 and 42,66 cpf]; Goffaux et al., 2011). In the present study, we favored a data-driven method similar to Bubbles (Gosselin & Schyns, 2001), allowing continuous sampling of SF and SO combinations across the whole spectrum. Seven participants performed 1,500 trials on a delayed same/different face matching task to reveal their combined SF-SO tuning. A broadband target face was shown for 300ms, followed by a 500ms white noise mask. A probe face, in which SF and SO were randomly sampled, was then presented until an answer was given. The task was to decide whether the probe matched the target or not. Results reveal a single channel with SF peaking at 15 cpf (width of 2.3 octaves) and SO peaking at 91 degrees (width of 15 degrees) was used to complete the task. This pattern of results replicates prior findings showing that face identification relies on limited information consisting of mid-to-high horizontal frequencies (Goffaux et al., 2011). However, use of a random sampling method gives a more complete picture, accounting for every possible SF-SO combination. Future work could benefit from such an approach to explore important issues like individual or cultural differences, thus potentially paving the way for adapted face training paradigms.

Poster Session C > Face Perception: Features and configurations > Poster C2

The Importance of Internal and External Features in Face Recognition

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Past research in the field of face perception has found that external facial features (hair, ears, face contour) better facilitate recognition of unfamiliar faces, whereas internal facial features (eyes, nose, mouth) support the recognition of familiar faces. In the current study, we investigate the differential use of internal and external features for the recognition of faces that vary in familiarity and race. White-Canadian participants (target sample size = 260) complete an online card sorting task in which they are given a set of cards containing photographs depicting individual faces. They are instructed to sort the cards into piles for each identity present in the set. Each participant sorts a set of cards with either own-race familiar, own-race unfamiliar, other-race familiar, or other-race unfamiliar faces. These faces are modified to contain only internal features, only external features, or both. Face recognition accuracy is measured by calculating the number of piles (or perceived identities) and the number of misidentification errors. Using a signal detection framework, we will calculate a sensitivity score for each participant to assess their recognition accuracy. Preliminary data from 44 adult participants in the whole face conditions reveal a) an own-race advantage in unfamiliar face recognition; participants perceived more identities when sorting other-race unfamiliar faces (mean = 6.93) versus own-race unfamiliar faces (mean = 4.89), and b) a familiar face advantage (mean = 3.98). We are currently recruiting 220 participants for the internal features and external features conditions and expect to find greater reliance on internal features for familiar faces and external features for unfamiliar faces. Moreover, we expect there to be a greater reliance on internal features for own-race as compared to other-race faces. These results will offer insight into how reliance on internal and external

facial features differs based on familiarity and race.

Acknowledgements: This research was supported by an NSERC Discovery Grant (RGPIN-2019-05548) to M.M

Poster Session C > Face Perception: Features and configurations > Poster C3

Interocular transfer of Flashed Face Distortion Effect

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The Flashed Face Distortion Effect (FFDE) is an illusion where faces viewed in rapid succession in the periphery are perceived as strongly distorted or caricatured (Tangen, Murphy, Thompson, 2011). The mechanisms contributing to the FFDE are largely unknown but could arise at many levels, including adaptation at both peripheral and central sites. Here we investigated whether pre-cortical processes play a role. For example, the response to each current image could be warped by local light adaptation or by Troxler-like fading of the preceding faces. To test for this we manipulated how successive faces are presented to each eye within a trial, using a dichoptic display. The faces (from the Karolinska Directed Emotional Faces, cropped to remove external features) within a trial were presented to either the left or right eye (monocular condition), both eyes (binocular condition), switched between eyes (interocular condition), or either the left or right eye but alternated with a gray field of the same duration between each face (control condition). The faces subtended a width of 3.3 degree with the closest edge at 2.5 degree eccentricity. Nine participants completed the conditions in randomized order, and used a sliding scale (from undistorted to very distorted) to rate the averaged level of face distortion at the end of each trial. We found that FFDE remained similar for interocular presentation - with comparable estimated distortion levels for monocular, binocular, and interocular conditions that were significantly larger than the control condition. These results suggest that early peripheral processes like local retinal adaptation, at least to the immediately preceding face may not significantly contribute to the FFDE.

Acknowledgements: This research was supported by the National Institutes of Health [EY010834 to MW, and P20GM103650].

Poster Session C > Face Perception: Features and configurations > Poster C4

The Effects of temporal rates on Flashed Face Distortion Effect and facial expression recognition

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A stream of face images can give rise to a variety of visual interactions, including adaptation, serial dependence, ensemble coding, and contrastive effects. We compared how the rate of presentation impacted two visual judgments – extracting the average expression across a set of faces vs. distortions in expression induced by the preceding faces (as in the flashed face distortion effect, FFDE). The faces were 5 different identities from the Karolinska Directed Emotional Faces, morphed between neutral and happy expressions (Experiment 1) or shown with neutral expressions (Experiment 2). The images subtended a width of 4 degree with the closest edge at 6 degree to the left and right of fixation, and were presented at a range of temporal frequencies (1.2Hz, 4.8Hz, 24Hz, and 60Hz). The total duration of the trial was fixed at 4.17s. 14 participant completed two sessions (one session for each experiment) in counterbalanced order. In the first experiment, the averaged facial expression presented in one visual field was the 50% morph level, and the averaged expression in the other visual field was either 35% or 65% morph level. A two-alterative forced choice task was used to identify which visual field had the stronger expression. In the second experiment, participants were asked to judge how distorted the neutral faces appeared on average. Over the range tested the FFDE decreased with temporal frequency while the accuracy of expression averaging increased. Our results indicate a transition from averaging to contrastive interaction (distortion) as the temporal frequency decreases.

Acknowledgements: This research was supported by the National Institutes of Health [EY010834 to MW, and P20GM103650].

Poster Session C > Face Perception: Features and configurations > Poster C6

I guess I just have one of those faces: The effect of similar intervening identities on familiarization

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People can become familiar with a target identity from different photos of the target interspersed among intervening distractor identities. We investigated whether the degree of similarity between a target face and these intervening distractors influences familiarization. Face space theory makes the clear prediction that similar identities would be encoded closely together in face space, creating interference from similar faces that hinders familiarization. In contrast, recent work showing an important role for idiosyncratic variability in identity learning suggests that increasing the similarity of irrelevant intervening distractors should encourage viewers to attend to the target's features that are most relevant for distinguishing it from the distractors, leading to a more refined and precise representation that would facilitate familiarization. Observers were trained with multiple photographs of a target identity presented among encounters with distractor identities that were morphed with the target face in varying percentages to achieve either high, medium, or low similarity to the target. Upon completing the training session, observers were given a matching task to test their familiarization with the target. Preliminary results revealed that accuracy in the matching task decreased as the similarity between the target and the intervening identities increased, providing support for the face space theory. Our results suggest that when learning a newly encountered target face, training with intervening distractors that highly resemble the target hinders the familiarization process.

Poster Session C > Face Perception: Features and configurations > Poster C8

Face gender versus identity in visual search and divided attention

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How is perceiving the gender of a face distinct from perceiving its identity? Here we report results from visual search and divided attention experiments that show differences in how faces are visually processed in each case. In our visual search experiments, we tested for visual field advantages in search performance. Observers searched for target faces in arrays of faces divided between the left (LVF) and right (RVF) visual fields. Faces were morphed such that target faces always differed from distractor faces by 30%. Crucially, this 30% morph difference corresponded to a change in either (a) morph but not identity, (b) identity only, or (c) identity and gender. Our results showed an RVF advantage for gender-based searches and an LVF advantage for identity-based searches. We interpret our findings as evidence of categorical perception of face gender but not identity. Our visual search results suggested serial processing in both cases, which we followed up using a divided field dual-task paradigm to test for potential differences in visual processing capacity limitations for face pairs (instead of six-face arrays). Our method allowed us to measure the cost of dividing visual processing resources between the two faces. Observers performed either a gender- or identity-based task, for one (single-task) or both of the faces (dual-task). In contrast to our visual search results, which showed no evidence of parallel face processing, we found that observers were able to judge the gender, but not the identity, of two faces in parallel. Taken together, our results show clear differences in the way faces are visually processed depending on the relevance of gender or identity to the task. Specifically, perception of face gender is left-lateralized and can occur in parallel whereas perception of face identity is right-lateralized and occurs serially.

Poster Session C > Face Perception: Features and configurations > Poster C9

Opposing aftereffects are still measurable after a one-week delay

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Introduction. Visual adaptation occurs after a sustained exposure to a visual stimulus. Aftereffects form after fixating a variety of visual stimuli, and the duration of the aftereffect varies depending on the visual stimulus (Burton et al., 2016; Leopold et al., 2005; Rhodes et al., 2007; Kloth & Rhodes, 2016; Kloth, & Schweinberger, 2008). The current study tests opposing aftereffects for Christian and Muslim faces 7 days after adaptation. Methods. Thirty-four participants underwent

an opposing after effect paradigm. First, participants viewed 48 face pairs, one compressed by 10% and one expanded by 10%, and on each trial selected which face looked more attractive. Next, participants were adapted to Muslim and Christian faces altered by 60%. After adaptation, participants again viewed and selected from the original 48 face pairs. Participants returned 7 days later and viewed and selected from the same 48 face pairs to determine if aftereffects were still measurable. Next, participants were re-adapted to Christian and Muslim faces distorted in the opposite direction and tested to see whether aftereffects could be reversed. Results. Using a mean change score for contracted faces selected from baseline as the dependent variable, there was a significant interaction between adaptation condition and religious face type ($F(1, 32)=6.18$, $p=0.018$) 7 days after adaptation. Examining adaptation conditions separately, opposing aftereffects were observed for those who adapted to Christian contracted and Muslim expanded faces, 7 days after adaptation ($t(17)=2.98$, $p= 0.009$). Opposing aftereffects could not be reversed by exposure to faces distorted in the opposite direction after 7 days, as no significant interaction between adaptation condition and religious face type was observed ($F(1, 32)=2.018$, $p=0.165$). Discussion. Results revealed evidence of opposing aftereffects adaptation persisting for 7 days. Furthermore, the aftereffect could not be reversed 7 days after adaptation.

Acknowledgements: This research was funded by a Social Sciences and Humanities Research Council (Canada) grant to MDR.

Poster Session C > Face Perception: Features and configurations > Poster C10

Encoding specificity in face memory: Face masks harm long-term memory for faces, but wearing the same (unique) mask each time is best

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How is long-term memory for faces impacted by the presence of uninformative face masks? In an initial across-subject experiment, subjects were tasked with remembering 40 faces without masks (N=20) and 40 faces with surgical masks (N=20). After a delay, they were presented with a 2-AFC memory test. Our results were consistent with existing research showing that face masks disrupt holistic processing (Freud et. al 2020), in that we found worse memory performance for masked faces than those without masks. The second experiment tested whether memory for faces is impacted by face masks that are known to be uninformative for the memory test, but are always present. Subjects (N=40) studied 80 faces each with uniquely patterned face masks. Critically, during the memory test, subjects were shown 40 “old” faces with the same unique masks originally studied, and 40 “old” faces with new unique masks that were not seen before. The 2-AFC always paired old faces with foil faces with matching masks to ensure the masks were not informative for discrimination. We asked (1) whether people effectively ignore masks during encoding and (2) how much a novel mask affects memory for a previously seen face. We found an encoding specificity effect: better performance for faces with unique masks that were the same at study and at test, compared to faces with unique masks which were different between study and test, even though memory for the mask itself was completely uninformative at test ($t(36)=3.30$, $p=0.002$, $d_z=0.54$). This was the case even though the instructions stated that masks will not be helpful for memory. Overall, these results suggest that face masks harm long-term memory for faces, and that face masks different from those which were encoded with the face further harm memory for faces, even when people are explicitly told to ignore the masks.

Poster Session C > Face Perception: Features and configurations > Poster C11

Recognition of emotions is affected by face masks

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Sarah McCrackin*[1], Francesca Capozzi*[1], Ethan Mendell[1], Sabrina Provencher[1], Florence Mayrand[1], Jelena Ristic[1]; [1]McGill University *Equal contribution

While masks are critical in mitigating disease contagion, they obscure facial features that are important for nonverbal social communication, i.e., emotions, intentions, or mental states. Here we investigated how nonverbal social communication is affected by mask wearing. We asked participants (n=117) to identify happy, angry, fearful, sad, surprised, disgusted, and neutral emotional expressions from masked and unmasked face images. Overall, the data indicated that both hit rate and sensitivity were reduced for all emotions when faces wore masks. Discrimination of disgust was impacted the most (52% reduction in sensitivity), indicating that recognition of this emotion relies strongly on information from the bottom of the face. Perception of sad (18% reduction), happy (15%), and surprised expressions

(15%) were impacted less while angry (12%), neutral (8%) and fearful expressions (7%) were impacted the least, indicating that the recognition of these expressions may be largely driven by information from the top of the face (e.g., eyes). Together these results reveal novel insights about the face features contributing to different emotion recognition and additionally suggest an important impact of the Covid-19 pandemic on human social communication.

Acknowledgements: SSHRC, NSERC, William Dawson

Poster Session C > Face Perception: Features and configurations > Poster C12

Perceptual factors underlie the underestimation bias in pain perception of black and white faces

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Communication of pain has been tied to the evolution of the human race, as efficient communication may increase chances of survival. Interestingly, underestimation biases in pain judgments are often observed and are even worse for ethnic/racial minority groups (Cintron & Morrison, 2006). It has been suggested that this form of racial biases in pain recognition could be due to the perceptual processes underlying the detection of the facial expression of pain (Mende-Siedlecki et al., 2019). However, the pain of others must not only be detected, but also evaluated in terms of intensity for one to exhibit the appropriate behavior. This study compared the pain intensity perceived in ethnic ingroup (white) versus outgroup (black) faces using the method of serial reproduction, known as “TeleFace” (Uddenberg & Scholl, 2018). 20 chains of 10 Caucasian participants were created (100 men) and one by one, 4 face avatars (2 gender x 2 ethnicity) displaying a medium intensity of pain (60%) were briefly presented to the first participant of each chain. The participant reproduced the perceived intensity using a slider along continuums of the same faces presenting different levels of pain intensity (from 0% to 100%). Its response was then used as the pain intensity for the next participant and so on down the line in each TeleFace chain. Results show that chains generally tend to converge toward a lower level of pain for black faces in comparison to white faces. Analysis on the intensity selected by the last participant of each chain revealed a significant underestimation of pain in black faces (M=34.10%, SD=12.68%) in comparison to white faces (M=44.03%, SD=11.49%) [$t(19) = 2.52$, $p=.02$, $d=0.82$]. These results suggest that viewers are influenced by face ethnicity when evaluating the intensity of the facial expression of pain in others.

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Poster Session C > Face Perception: Features and configurations > Poster C13

Visualizing Androgynous Faces Using Reverse Correlation

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Images of androgynous faces typically are generated by morphing masculine and feminine faces, based on an assumption that androgynous faces are equally masculine and feminine. Our past work (VSS 2020) challenged that assumption, finding that androgynous faces could be perceived simultaneously as both androgynous and strongly gendered. The current study uses a reverse correlation technique (Dotsch & Todorov, 2011) to address directly the question of what makes faces appear more or less androgynous. On each of 600 trials, an observer viewed a pair of male or female faces embedded in Gaussian white noise and chose the face that appeared more androgynous. The two noise fields varied across trials, but were anti-correlated within each trial. Noise fields were sorted based on observer responses, and averaged to create a Classification Image (CI) and an antiCI. Initial results from two female observers showed that when the CI and antiCI were added to base faces with the same gender as their original base, resulting images clearly differed, with base-face+CI less strongly gendered (more androgynous) than base-face+antiCI. Interestingly, adding the CI and antiCI to the opposite gender face had the opposite effect: a CI obtained from a female base-face made a male base-face appear more masculine, whereas the antiCI made the male face appear more androgynous. We currently are conducting statistical analyses and behavioural experiments to examine i) how the

spatial structure in the CI varies across base face images; and ii) the consistency of CIs across observers. We also plan to repeat the study with more faces, tasks, and observers to determine the limits of generalizability, and to determine more precisely the relationship between androgynous CIs and gendered CIs. The results of these studies will shed much needed light on our understanding of how the visual system processes face gender information.

Acknowledgements: NSERC

Face Perception: Individual differences 2

Poster Session C > Face Perception: Individual differences 2 > Poster C14

Training on groups of similar faces decreases similarity both within and between groups

View Poster | Visit me in Gather.Town Osprey Room on Sunday 4:00 pm - 6:00 pm EDT

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Face perception is likely influenced by experience, and people may frequently encounter groups of relatively similar faces, e.g. from the same family, or 'race.' Can observers learn to establish visual representations for groups of faces, making groups that initially appear similar more distinct? We tested this idea by training observers on two groups of faces and measuring perceived similarity. Groups of 5 faces were defined using an established 'face space' that represents differences in geometric features as distance. Faces within a group were close to each other, compared to randomly selected faces, and the two groups were also relatively close. Human observers then viewed two faces at a time and rated, from 1-5, how similar the pairs were, for all possible pairings of the 10 faces. We next trained observers to identify members of the groups using a visual search task. Target and distractor faces were chosen from the same group, and the two groups were trained in alternate sessions. Observers completed two visual search sessions a day for three consecutive days. Following training, we again measured perceptual similarity. Overall, face pairs from the same group were rated as more similar than pairs from different groups. Faces appeared less similar following training; the mean similarity rating for pairs within the same group increased significantly, ($m=.91$, $p<0.01$). Critically, the mean rating for pairs from different groups also increased ($m=.56$, $p<0.01$). A 2D multidimensional scaling solution additionally showed that the distance between the centroids of the two groups increased (by 0.36). These results suggest that experience can alter how our visual system represents groups of faces, decreasing similarity both within and between groups. Bringing the appropriate group-level representation to bear on frequently-encountered groups may improve performance on tasks such as identification or recognizing expressions.

Acknowledgements: This study was funded by NSF BCS-1558308

Poster Session C > Face Perception: Individual differences 2 > Poster C15

Face dominance modulates the perceived face size: converging evidence from three countries

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Perceived social traits, such as dominance and trustworthiness, affect other people’s behaviour. For example, gaze following behaviours are modulated by perceived face dominance (Ohlsen et al., 2013). While the impact of social traits has been consistently found in high-level face perception, it is unclear whether social traits also influence low-level facial information processing. To this end, we investigated how perceived face dominance affects the perception of face size. We used a robust perceptual illusion to measure the perception of face size: when two identical faces are presented vertically (one above the other), the bottom one appears bigger (Sun et al., 2012). We hypothesize that if face dominance modulates the perception of face size, this will be reflected in the magnitude of the illusion. We used a set of Dominant and Submissive computer-generated faces (Oosterhof & Todorov, 2008), which were verified by human raters. Participants saw two identical vertically presented faces and used the mouse to decide which face was bigger. To probe the generality of this effect, we tested this effect across three countries ($N = 30$/country) with faces from three

races (African, Asian, and Caucasian). Across the three countries, participants showed a significant bias in choosing the bottom face as the bigger one (Mean bottom responses = 72.03%, $p < .001$), replicating the illusion. More importantly, Dominant faces led to a stronger illusion than Submissive faces ($p = .009$), suggesting face dominance modulates the perception of face size. We did not find a significant effect of face race or country. Together, the converging findings from the three countries indicate that perceived dominance amplifies the perceived size of the bottom face. This effect supports a top-down perceptual modulation account, by which high-level representations of social traits influence low-level visual processing.

Impact of sustained lifetime exposure to a racially-heterogenous face-diet

View Poster | Visit me in Gather.Town Osprey Room on Sunday 4:00 pm - 6:00 pm EDT

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Face-diets of observers living in racially-homogeneous environments are predominantly composed of own-race faces resulting in a lack of experience with other-race faces (Sugden et al. 2014; Oruc et al. 2019). According to the contact hypothesis, this, in part, leads to a marked impairment in the ability to recognize other-race faces, termed the other-race effect. However, the contact hypothesis does not predict what impact a racially-heterogenous face-diet with plenty of exposure to multiple face races may have on face expertise. To complement and extend the contact hypothesis, we propose three new models: (1) the experience-limited, (2) the capacity-limited, and (3) the enhancement hypotheses for the role of exposure in face expertise. Based on the experience-limited account native-level face recognition can be achieved for multiple face races with sufficient experience. On the other hand, the capacity-limited account predicts exposure to multiple face races may impact face expertise detrimentally. Lastly, based on the enhancement account exposure to a racially-heterogenous face-diet may confer some advantages in face expertise. Here, in two experiments, we compared face recognition in a dual-exposure group ($N = 20$) with sustained high exposure to Caucasian and East Asian faces to two mono-exposure groups ($Ns = 20$) with sustained exposure to either Caucasian or East Asian faces only. We found native-like recognition performance in the dual-exposure group regarding face memory and face inversion effect for both Caucasian and East Asian faces. Our results showed neither an advantage, nor a disadvantage for racially-heterogenous face exposure, hence supporting the experience-limited account of face expertise. Consequently, we conclude that exposure to multiple face races is not detrimental to face recognition ability. To achieve native-level face expertise, a racially-homogenous face diet is not a necessity.

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The preferred fixation location on the face modulates the locus of the Composite Face Effect

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Introduction: Faces are recognized best when individuals look close to their own distinct preferred fixation location (PFL), with some preferring to look down toward the nose tip and mouth while others prefer to look up toward the eyes (Peterson & Eckstein, 2013). Here, we investigate whether individual differences in the preferred point of fixation modulate the composite face effect (CFE). Specifically, we test whether the variation in the strength of the CFE for top and bottom face halves depends on the PFL. Methods: Sixteen eye-lookers and sixteen nose/mouth-lookers were screened through a free eye movements face identification task from a pool of 126 observers. The selected observers then completed a free eye movement face identification task with 4 composite faces. A subsequent parts matching task consisted of observers matching top or bottom face halves (block dependent) across two sequentially presented aligned or misaligned (block dependent) composite faces (50% matched, 50% unmatched, 200 msec.). Across trials, observers maintained their fixation at the mean preferred fixation point of their group or the mean of preferred fixation point of the other group. Results: We conducted a 3-way repeated measures ANOVA on the CFE (PCmisaligned – PCaligned) with

the looker type, fixation location and the half being judged as factors. We found a significant main effect of the half being judged (F (1,120) =29.26, p << 0.05) and a significant interaction between the looker type (eye vs. nose/mouth looker) and half being judged (top vs. bottom; F (1,120) = 8.74, p = 0.0037). A post-hoc Welch test with FDR correction confirmed that eye lookers showed a significantly stronger CFE at the top half as compared to the bottom half (t (62) =2.94, p = 0.0046). Conclusion: The findings suggest that the preferred point of fixation might modulate the locus of the Composite Face Effect.

Poster Session C > Face Perception: Individual differences 2 > Poster C18

Looking-at-nothing: an ocular motor index of face recognition in control subjects and developmental prosopagnosics

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When subjects are shown visual stimuli and then have to perform a task involving these stimuli after they have disappeared from the screen, they still tend to fixate the regions where those stimuli had been located, an effect called ‘looking-at-nothing’. We conducted three experiments to examine whether this effect could act as an implicit index of face recognition in both control subjects (n = 48) and individuals with developmental prosopagnosia (n = 8). On each trial, a subject saw a 3-second video of a person’s face and then saw a choice screen of four faces for 1.2 seconds. This was followed by a response screen with empty boxes, at which point they had to respond whether the face in the video had been present in the preceding choice screen. We analyzed the fixations made while subjects were viewing the response screen (without faces present). Control subjects were more likely to fixate the empty box where the target face was presented, The frequency of this looking-at-nothing effect was greater on hit than on miss trials. Conversely, the odds of a correct response were increased if the first fixation was made within the empty target box. The temporal dynamics of the looking-at-nothing effect showed that it was present for the first fixation only and then transitioned to reduced fixations on the empty target box. Across subjects there was a positive correlation between discriminative sensitivity and the frequency of the looking-at-nothing effect. Developmental prosopagnosic subjects showed a similar effect but reduced in magnitude, with the looking-at-nothing evident on hit but not miss trials. We conclude that the looking at nothing effect can index rapid face recognition in both control and developmental prosopagnosic subjects, and that it is correlated with explicit discriminative performance.

Poster Session C > Face Perception: Individual differences 2 > Poster C19

Social motivation in autism and developmental prosopagnosia

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According to the social motivation hypothesis, low social motivation and impairments in face processing are implicated in the development of Autism Spectrum Disorder (ASD). The face deficits are thought to come about, in part, due to low social motivation and disruption of visual experience necessary for the development of expert face recognition (Chevallier et al., 2012; Schultz, 2005; Oruc et al., 2018). Conversely, impaired face abilities in autism may be a cause rather than a consequence of lowered social motivation. To examine the directionality of this potential relationship further, we examined adults with developmental prosopagnosia (DP), adults with ASD, and a neurotypical control group. We used the Cambridge Face Memory Test (Duchaine & Nakayama, 2006) to assess face recognition, and the Multidimensional Social Competence Scale (Yager & Iarocci, 2013) to assess social motivation. There was a significant main effect of group (F(2,86) = 43.19, p < .001) where face recognition accuracy was highest in controls (M = 81.9%), significantly reduced in ASD (M = 66.5%) and lowest in DP (50.18%) (p<.05 for all comparisons). A main effect of group was also found for social motivation (F(2,86) = 11.67, p < 0.001), which was highest in controls (M = 40.33), but did not differ significantly between ASD (M = 31.82) and DP (M = 34.04) groups. Reduced social motivation in the DP group compared to the controls suggest that deficits in face recognition may contribute to low social motivation in this group. Yet, greater severity of face deficits in the DP group, compared to the ASD group, do not lead to further reductions in

social motivation. Together, these results suggest that any effects of face recognition impairments on social motivation are limited in nature and unlikely to account for low social motivation in ASD.

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Poster Session C > Face Perception: Individual differences 2 > Poster C21

Individual differences in the spatial localization of upright versus inverted faces

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Localizing objects is a fundamental function of vision, a prerequisite for most other high-level perceptual and motor goals. Localization could be object invariant: the perceived position of an object may not depend on its particular identity. This would support the commonly held assumption that localization emerges from a unified process or a single module in the brain (e.g., constant retinotopy maintained throughout the visual hierarchy, or a privileged area like FEF that signals perceived position). An alternative is that object representations do influence position assignment. To test this, we measured individual differences in the localization of upright and inverted faces. We employed a dual-task localization and recognition paradigm. On each trial, a grayscale face was briefly presented (either upright or inverted) enveloped within a Gaussian contrast aperture. The face was shown at one pseudo-randomly chosen angular location with fixed eccentricity. Upon its disappearance, observers first moved the cursor to indicate the center of the face, and then they reported its gender (female/male). Collapsed across subjects, at the group level, there was no obvious difference in localization performance for upright and inverted faces. However, the results revealed significant individual differences: each observer mislocalized the stimuli at different locations of the visual field, and these localization biases were stable, consistent with previous findings (Kosovicheva & Whitney, Curr Bio, 2017; Wang et al., Proc Roy Soc, 2020). More importantly, we found that observers showed different idiosyncratic localization biases for upright and inverted faces. The precision of the localization was similar for upright and inverted faces, suggesting that attention differences and lapsing were not likely responsible. Instead, stimulus-specific (for example, face-specific) position coding mechanisms likely exist. The results undermine the idea of a modular or single retinotopic pathway to localization, and instead suggest that object identity interacts with the assignment of perceived position.

Color, Light and Material: Lightness and brightness

Poster Session C > Color, Light and Material: Lightness and brightness > Poster C41

Neural edge integration model with different weights for positive and negative luminance steps explains lightness scaling in the Staircase Gelb effect

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Lightness matches made to papers in Staircase Gelb and modified Staircase Gelb displays were modeled with a neural model of lightness computation based on the principle of edge integration. To compute lightness, the model sums logarithmic steps in luminance at the edges of all papers in the display along paths directed towards the target paper, with edge weights that depend on two independent factors. Factor 1 is the distance of an edge from the target. Factor 2 depends on whether the luminance step at the edge increments or decrements in the target direction. Factor 2 was estimated from quantitative fits to ON- and OFF-cell responses in macaque LGN (De Valois, Abramov, & Jacobs, 1966; Billock, 2018). In the perceptual experiments, grayscale papers were arranged either: 1) from lowest to highest reflectance in a spotlight (Zavagno, Annan, & Caputo, 2004, Series A); 2) with the papers spatially reordered such that the highest reflectance paper neighbored the lowest reflectance paper (Zavagno et al., Series B & C); or 3) as in (1), but with an white border surrounding the display (Gilchrist & Cataliotti, 1994). The neural model reproduced to within 1.6% error the average lightness matches made in these experiments. It accounted for both the overall magnitude of dynamic range compression observed when the papers were spatially well-ordered, and various releases from compression that were observed when the papers were spatially reordered. It also reproduced the observation of Gilchrist and Cataliotti that surrounding the display with a white border brings the perceived reflectance scale more in line with the true ratio scale of the physical paper reflectances (ground truth). These results demonstrate that a plausible neural model of lightness, having parameters derived from physiology, can explain the quantitative lightness scaling of real material surfaces viewed under spotlight illumination in these experimental conditions.

Acknowledgements: The author is supported by NIH COBRE P20GM103650.

Poster Session C > Color, Light and Material: Lightness and brightness > Poster C42

A history and modular future of multiscale spatial filtering models

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Human lightness perception is remarkably robust against fluctuations in the sensory input – a feature that yields impressive visual illusions and has been subject of extensive psychophysical study for testing perceptual mechanisms proposed to be involved. Modern computational methods additionally have made it possible to investigate how aspects of neural processing might lead to non-veridicality in lightness perception as an emergent property — rather than resulting from specific mechanisms or strategies. Particularly successful is modeling lightness perception using spatial filtering at multiple spatial scales. While not capturing all non-veridicalities, these models are representative of early visual processing and can qualitatively predict perceptual responses to many stimuli. To combine such multiscale spatial filtering models with other proposed mechanisms of lightness perception, we ask which model components have proven useful to explain lightness perception in general (and to what degree), and which components are necessary only when explaining specific phenomena from specific models. We provide a historical roadmap the evolution from earlier to contemporary models, as well as a schematic overview of major differences between models and their effect on resulting model predictions. The schematic overview also made possible an accompanying new, modular, implementation of spatial filtering models. The `multyscale` Python package is fully open-source, with no dependency on proprietary software. It implements several multiscale models, and provides documented examples, demos and tutorials for the models and related topics. The powerful modular implementation is demonstrated, by predicting perceived lightness in a psychophysical paradigm, in detail that would have been difficult and (computationally) time-consuming with previous implementations. Proof-of-concept is given for fitting model parameters to psychophysical data, going beyond the use of previous implementations. Future endeavors can take advantage of the modular nature, by integrating elements of multiscale spatial filtering with either mechanistic approaches (e.g., contour integration) or statistical (e.g., deep learning).

Poster Session C > Color, Light and Material: Lightness and brightness > Poster C43

Luminance dictates arousal-based pupil modulation

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Pupils constrict and dilate in response to changes in retinal illumination, as well as in response to endogenous factors such as arousal state. However, the interaction between luminance and arousal state on pupillary responses remains relatively unknown. In this study, we sought to examine this interaction by parametrically assessing luminance-driven pupillary responses while concurrently manipulating arousal. To measure the pupillary light response profile, participants viewed a display that varied in luminance. To modulate cognitive arousal, participants concurrently performed a task comprised of auditory math problems, for which cognitive effort was manipulated using Easy (low arousal) and Hard (high arousal) problem sets. Replicating previous work, we found that participants all exhibited nonlinear pupillary light reflexes. To quantify the pupillary light function, and its changes with arousal level, we fit the pupillometry data with a hyperbolic ratio function. At the group-level, our results revealed that the greatest overall modulatory effect of arousal on the pupillary light function occurred at low and mid-luminances—indicating that the modulatory effect of arousal on pupil size multiplicatively interacts with luminance. However, we found that at the level of individual participants, there were qualitatively distinct individual differences in the modulatory effect of arousal on the pupillary light function. These findings have the potential to reshape interpretation of previous pupillometry work, while offering insight and suggestions

into the selection of optimal luminances in future pupillometry work.

Poster Session C > Color, Light and Material: Lightness and brightness > Poster C44

Measurement of the omitted-stimulus response within the retina

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People with schizophrenia demonstrate impairments in predictive coding, particularly in laboratory tasks that assess high-level visual perception. However, it is unclear whether these abnormalities extend to the sensory level of vision. To date, only three studies have focused on retinal predictive processing within human subjects (Gowrisankaran et al., 2013; McAnany et al., 2013; McAnany & Alexander, 2009). This has been done through measurement of the omitted-stimulus response (OSR), which reflects the retinal response to an omission embedded within a highly repetitive stimulus train. The present study examined whether an OSR could be observed within human retinal activity to inform future studies focused on how these processes may be impaired in schizophrenia. Flash electroretinography (fERG) was recorded while eighteen subjects viewed a series of light flashes within two conditions: (1) a single-flash condition at 1.96 Hz and a luminance of 85 Td · s; and (2) a flicker condition at 28.3 Hz and a luminance of 16 Td · s. We examined the mean ERG waveforms of the retinal responses for present-stimulus and omitted-stimulus responses. Results demonstrated the absence of an OSR within the single-flash condition. We found the presence of a diminished (M=9.26) and delayed (Mdn=37.89) OSR peak within the flicker condition when compared to the present-stimulus amplitude (M=16.37) and implicit time (Mdn=29.70) measurements ($t(17)=7.59$, $p<.001$; $z=2.12$, $p=.03$, respectively). Additionally, OSR amplitude was highly correlated with number of flashes prior to first omission ($r_s=.56$, $p=.02$). Overall, findings suggest that the retina elicits a response to an omitted stimulus embedded within a flicker train, although it is unclear whether this is representative of predictive or resonant activity. Additional studies are warranted to assess whether this activity is reduced in people with schizophrenia and whether it can serve as a marker of cortical predictive coding integrity.

Color, Light and Material: Color 1

Poster Session C > Color, Light and Material: Color 1 > Poster C45

Color similarities assessed by phase matching

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The relationships between large color differences are important for understanding the perceptual organization of color. We examined these in a novel phase matching task. Two juxtaposed chromatic gratings defined by different colors (e.g. one red-green and the other orange-cyan), appear more clearly aligned in one phase (e.g. red with orange) than the other (e.g. red with cyan). We used this effect to explore the pairings between different directions in color space. Stimuli were horizontal equiluminant gratings (0.5 c/deg), and subtended 2x8 deg on the mean gray background (20 cd/m2). Contrast varied sinusoidally over +/-80 nominal units along directions at 22.5-deg angles in the cone-opponent plane. A fixed reference axis (e.g. LvsM) was shown in the center of the screen, and was abutted by a test grating (e.g. SvsLM) displayed with opposite phases on the left and right sides. Observers chose which test phase appeared better aligned with the reference grating. The test angle randomly varied across trials with each of the 8 angles shown 10 times to estimate the “orthogonal” color direction at which the two phases were chosen equally. These nulls varied systematically with the reference angle but showed consistent individual differences, and for some observers exhibited plateau-like steps suggesting possible categorical biases. Each observer also selected (from a circle showing 36 color directions) the angles corresponding to their unique and binary hues. From these we estimated the perceived hue of the gratings and their nulls. Orthogonal differences in the perceptual space provided a poorer account of the nulls than orthogonal directions in the LvsM and SvsLM plane, yet for both deviations were evident. These deviations and the individual differences could in part reflect differences in the salience of the two hues within a grating, for example in terms of which

hue is perceived as the “foreground” color.

Acknowledgements: Support EY-010834

Poster Session C > Color, Light and Material: Color 1 > Poster C46

The Temporal Clocking Rates of Where (Dorsal) and What (Ventral) Visual Systems: Measurement of Motion and Color-Hue Direction Thresholds

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Introduction: We tested stimulus discrimination speeds associated with the Where (Dorsal Stream) and What (Ventral Stream) visual processing systems. The dual-stream model of neural processing specifies that the Where System is used for rapid perception-action and general motion-processing tasks, while the What System is used to distinguish object related information like type and color. Our study measures the fastest rates for discriminating motion and hue direction, as respective metrics of Where and What System processing speeds. Method: To measure the Where System processing rate, four LEDs, arranged in a diamond configuration, were successively flashed on and off in either clockwise or counter clockwise direction. Ten participants judged direction, with presentation speed following a staircase procedure to determine temporal thresholds. To measure the What System processing rate, a disk lit with equal luminance LEDs successively cycled through the hue circle in either CW or CCW direction (red-green-blue… or red-blue-green-…). The same participants judged hue change direction, again with a temporal staircase procedure. Results: The mean speed threshold for processing CW vs CCW direction was statistically the same for all colors at 19.15 Hz per cycle (equals 76.60 individual LED flashes per second). The mean speed threshold for processing hue direction was 2.28 Hz per cycle (equals 6.84 individual colors per second). The two processing speed rates statistically differed ($\Delta\mu$=16.87Hz, $t(9) = 11.31$, $p<0.001$, $d=4.97$). Discussion: Our findings support a Where System processing rate of around 20 Hz, consistent with classic findings of flicker fusion rates. They also support a What System processing rate of about 7 Hz consistent with preferred temporal rates of higher level cognitive processes like shape discrimination judgments and preferred speech syllable rate. These findings support the distinction of two visual processing systems and provide a metric for neural research that examines relative dorsal and ventral processing rates.

Acknowledgements: ASU SciHub

Poster Session C > Color, Light and Material: Color 1 > Poster C47

Can variations in luminance sensitivity predict variations in the cardinal color directions?

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Color vision investigations often employ the concept of a color space based on a standard observer with standard cone fundamentals and cone ratios to calculate the relative activations of the cones and opponent mechanisms. However, since there are large variations in individuals’ cone fundamentals and luminosity function, each observer has their own unique color space. It would often be beneficial to account for these individual differences, particularly when attempting to study isolated cone or opponent mechanisms. While techniques for measuring individual cone fundamentals and establishing unique color spaces already exist, they are impractical and time-consuming for most applications. We have previously modeled how easily-measured luminance settings of an observer might be used to predict individual differences in color space due to their shared sources of variability. Here we report results of an empirical test of the ability of luminance differences to predict individual cone opponent axes. To estimate the tilt of the equiluminant plane we employed a minimum motion task to stimuli modulated along the assumed opponent axes. To locate the individual opponent axes, we used an established adaptation/contrast-matching paradigm (Webster et al, 2000). For both tasks we included measurements from both the fovea and at 4-deg in the periphery wherein the values should vary significantly within an observer due to macular pigment and other retinal inhomogeneities. As predicted by our previous model, we found a strong correlation (r = .72, p=.003) between measures of luminance evidenced as a tilt in the equiluminant plane and estimates of the location of the SvsLM opponent axis revealed as a rotation within the equiluminant plane. These results are consistent with our previous modeling in suggesting that standard and relatively accessible measures of equiluminance can be employed to also refine the estimate of the chromatic directions that isolate the cone-opponent mechanisms.

Acknowledgements: Support EY-010834

Poster Session C > Color, Light and Material: Color 1 > Poster C48

Rayleigh Matching With Multiple Reference Wavelengths Improves Estimation of L and M Photopigment Lambda Max and Optical Density

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Individual differences in human L and M cone fundamentals occur because of differences in wavelength of photopigment peak spectral sensitivity (lambda max) and differences in photopigment optical density. Although Rayleigh matching can be used to estimate these parameters, changes in lambda max and optical density are confounded when a single reference wavelength is used (Thomas & Mollon, 2004). Here we evaluate the use of Rayleigh matching with multiple reference wavelengths to estimate these parameters. We simulated Rayleigh matches using a mixture of two narrowband primaries (560 and 670 nm peak power) and 15 narrowband reference lights (peaks between 570 and 640 nm). Mixing ratio and reference intensity at the match were determined by computing cone excitations and bringing these into agreement via an interleaved staircase procedure with simulated forced-choice redder/greener and lighter/darker comparisons. We varied cone fundamentals using the Asano et al. (2016) model of population variation in lambda max and optical density. We then fit the model parameters to best account for each simulated observer's matches and computed the mean RMSE (20 observers) between simulated and recovered cone fundamentals. For comparison, we also found the RMSE between simulated and standard cone fundamentals. Our procedure recovered L and M cone fundamentals well. The RMSE between simulated and recovered fundamentals was 0.00046, compared to 0.0076 obtained by using the standard fundamentals. The RMSE obtained from simulations with the best single reference wavelength (620 nm) was 0.0026. Our results indicate that Rayleigh matching with multiple reference wavelengths can resolve ambiguity about L and M cone fundamentals that occurs when a single reference wavelength is used. This could improve estimation of individual observers' L and M cone fundamentals, although experimentation that accounts for the precision of real observer matches will be required to validate the approach.

Poster Session C > Color, Light and Material: Color 1 > Poster C49

Modeling the Effect of Aging on Equiluminance Settings

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In our previous work, we reported measurements of heterochromatic flicker photometry (HFP) in 22 young observers, with stimuli that (nominally) modulated only L- and M-cones, and were kept at (approximately) a constant multiple of detection threshold (He, Taveras Cruz, & Eskew, 2020). These equiluminant settings were represented as the angle in the (L,M) cone contrast plane, with the "greenish" peak of the flicker in quadrant II and the "reddish" peak in quadrant IV; equiluminant settings were reported as the 'greenish' angle. The mean equiluminant angle was 116.3° (a M/L cone contrast ratio of -2 at equiluminance), for observers with an average age of around 20 years old. However, HFP settings can vary substantially with age, mostly due to changes in lens optical density, the dominant element of ocular media optical density (Sagawa & Takahashi, 2001). In the present study we sought to model the expected variations in equiluminant angle resulting from the effect of aging. For this purpose, we assume that all observers have the same equiluminant angle when analyzed with their own cone fundamentals. We then modeled the apparent change in equiluminant angle that results from varying ocular media optical density from age 20 to 60 when the data are analyzed using standard cone fundamentals. The ocular media density curves for the young and elder observers were estimated based upon the model developed by van de Kraats and van Norren (2007), while the density curve for the standard observer was obtained from Stockman, Sharpe, and Fach (1999). In standard cone coordinates, the measured |ΔM/M:

ΔL/L| ratio increases by almost 0.9 with aging. Unsurprisngly, the effect of increasing ocular media density is to produce an apparent reduction in relative M-cone contribution to the strength of the luminance mechanism,with that change solely being the result of changes in cone fundamentals.

Acknowledgements: This work was supported by NSF BCS-1921771.

Poster Session C > Color, Light and Material: Color 1 > Poster C50

Warm vs. cool colors and their relation to cone-opponent and perceptual-opponent dimensions

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The distinction between warm vs. cool colors has been widely invoked as a fundamental dimension of both color appearance and color emotion. We examined how this dimension varied among observers and the relationship to both the cone-opponent dimensions of early color coding (LvsM and SvsLM cardinal axes) and the perceptual opponency of color appearance (red-green and blue-yellow). Observers viewed a sample of 36 stimuli with a fixed nominal (~multiple of threshold) contrast of 80 and spanning the cone-opponent plane in 10-deg steps. Each was shown individually on an equiluminant (20 c/m2) gray background and pulsed 500-ms on, 150-ms off while observers rated the warm-cool attribute on a 7-point scale (ranging from very cool to neutral to very warm). Four measurements were made for each stimulus in random order. In a second set of measurements, the full set of 36 hues were displayed as a circle on the screen and the same observers varied a pointer to select their best example of the four unique (e.g., red or yellow) and four balanced binary hues (e.g., a 50%-red, 50%-yellow orange), again with four settings for each. The two boundaries for warm vs. cool were estimated from polynomial fits to each observer's ratings. These loci varied substantially across observers but in almost all cases fell within the first and third quadrants of the cone-opponent space (corresponding to purplish reds and green to yellowish-greens). Inter-observer variability was larger for the warm-cool boundaries than the hue loci and showed weak to no correlations with each other or the hue loci. These results suggest that warm-cool judgments correspond to a dimension of color appearance independent of both the cone-opponent and perceptual-opponent axes; and to a dimension that tends to vary along bluish to yellow/orange axes, which are prominent axes of variation in natural illumination and environments.

Acknowledgements: Supported by EY-010834

Poster Session C > Color, Light and Material: Color 1 > Poster C51

Anomalous color vision and wide gamut LED lighting

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For general use, lighting should not distort the color appearance of familiar objects. However, in special cases color distortion may be desirable. It is well-known that some spectral power distributions can increase the apparent chroma of objects, generally along a selected axis in color space, and always with a consequent distortion of hue. It is interesting to consider whether some individual observers could benefit from spectral tuning of this type. In particular, there is considerable interest in filters worn as glasses (such as those under the trade name EnChroma), which increase the contrasts of LvsM-cone color differences for individuals with diminished LvsM sensitivity. Instead of filtering the light just before it enters the eye, logically the same effect can be achieved by filtering the light source, or equivalently, by selecting an approximately equivalent combination of narrow-band LEDs. We have compared calculated color shifts produced by 3-primary narrowband LED sources to those for EnChroma-filtered broadband light, by simulating the cone-opponent responses of color deficient and trichromatic observers. We notionally illuminated the spectral reflectance factors of Munsell surfaces that were selected to yield a uniform circle of 36 hues in a cone-opponent space under equal energy white for a standard trichromatic observer. Chromatic contrasts were determined for the LED sources and the filtered broadband light, both for normal trichromats and observers who were deuteranomalous or protanomalous. For all observer types, we found qualitatively similar patterns of contrast enhancements for the two sources, confirming that narrowband LED luminaires may be a viable approach for enhancing color contrast for anomalous trichromats. However,

in previous work we also found that color-normal observers adapt to the higher chromatic contrasts generated by wide-gamut LED sources (Takahashi et al. JOV 2019). Thus, the consequences of these adaptation effects should also be evaluated for color-deficient observers.

Poster Session C > Color, Light and Material: Color 1 > Poster C52

High-resolution functional MRI responses to chromatic and achromatic stimuli in V1 and V2

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The non-human primate (NHP) visual system processes color and form in separate (but interacting) pathways. While post-mortem studies have suggested that these pathways in human V1 and V2 are similar to NHP V1 and V2, in that they have superficial cytochrome oxidase blobs and thin stripes associated with color processing, this has been challenging to validate in vivo. Recent advances in high-resolution neuroimaging have facilitated the mesoscopic-scale exploration of the human visual cortex. Here we used 7T fMRI to investigate differences in V1 and V2 activation to chromatic vs achromatic stimuli in five subjects across two scanning sessions. Achromatic checkerboards with low spatial frequency and high temporal frequency targeted the color-insensitive magnocellular pathway and chromatic (red-green) checkerboards with higher spatial frequency and low temporal frequency targeted the color-selective parvocellular pathway. This work resulted in three main findings: First, responses driven by chromatic stimuli had a laminar profile biased towards superficial layers of V1, compared to responses driven by achromatic stimuli. This is consistent with the finding of strong color selective responses in the cytochrome oxidase blobs in the superficial cortex of NHPs. Second, parafoveal V1 displayed a stronger preference for chromatic stimuli compared to peripheral V1. This is consistent with behavioral studies that have demonstrated decreasing sensitivity to red-green color contrast with increasing eccentricity. Finally, we found alternating, stimulus-selective bands stemming from the V1 border into V2 and V3 across both sessions. Similar alternating patterns, termed "stripes", have been previously found in both NHP and human extrastriate cortex. Our data show similar band sizing in V2 as in previous human histology studies. Together, our findings provide a strong in vivo validation that the organization of color and form processing in V1 and V2 is as predicted from previous NHP and post-mortem studies.

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Color, Light and Material: Cognition and preference 1

Poster Session C > Color, Light and Material: Cognition and preference 1 > Poster C53

More of what: does the dark-is-more bias for colormap data visualizations operate on numeric or conceptual magnitude?

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When interpreting colormap data visualizations, people infer that darker colors map to larger quantities (dark-is-more bias). In the colomaps tested in previous studies, numeric magnitude always corresponded to concept magnitude (i.e., # of animals corresponded to “greater” animal sightings) (Schloss et. al., 2019; Sibrel et al., 2020). However, conflicts can arise in which larger numeric magnitude corresponds to smaller concept magnitude. For example, if number of seconds is used to represent the concept of speed, then larger numbers correspond to less speed. Under such conflicts, does the dark-is-more bias operate at the numeric or conceptual level? In Experiment 1, participants interpreted colormaps representing fictitious data on the time alien animals took to notice a scientist observing them. The “congruent group” (n=30) was told the colormaps represented duration, with larger numbers on the legend labeled “longer” (more duration)

and smaller numbers labeled “shorter” (less duration). The “incongruent group” (n=31) was told the colormaps represented speed, with larger numbers labeled “slower” (less speed) and smaller numbers labeled “faster” (more speed). Participants indicated whether the time was longer/faster for animals represented on the left or right side of the colormap. The design included 2 numeric encoded mappings (dark-more/light-more) x 2 color scales (Hot/Colorbrewer-blue) x 2 legend label positions (more-high/more-low) x 20 repetitions (320 trials). The congruent group showed a dark-is-more bias, with faster response times for dark-more numeric encoding, but the incongruent group showed the opposite effect (interaction: p<.001). This suggests that the dark-is-more bias operates at the conceptual level. Experiment 2 was like Experiment 1, except without concept labels on the legend. Here, both groups were faster for dark-more numeric encoding (p<.001; no interaction p=.093). Thus, interference from the conceptual level may be confined to cases where concepts are explicit in visualizations.

Poster Session C > Color, Light and Material: Cognition and preference 1 > Poster C54

Political party affiliation alters implicit color processing as measured by attentional filtering of distractors

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Previous research has shown that color preference is affected by the environment and often changes due to social settings (sports teams, college allegiances, etc; cf. Schloss & Palmer, 2017). In this experiment, we utilized the United States two-party political system as a social backdrop upon which to measure the effect of color-party association on both explicit and implicit biases. We tested 451 subjects through Amazon’s Mechanical Turk; approximately half during summer of 2016, and the other half on the 2016 presidential election day (November 8). We implicitly measured the effect of color on attentional filtering of distractors by having participants complete an Eriksen flanker task with a white target letter and red or blue flankers (blocked by color). They then explicitly rated their color preference on a 16-color array, which included the same red and blue colors from the flanker task. Finally, subjects completed a political demographic survey, where they indicated their political affiliation and voting history. Color preference data showed that, on election day, Republicans experienced a decrease in their preference for blue but were more distracted by red flankers; while Democrats showed no change in color preference on election day but were more distracted by blue flankers. Due to this dichotomy between implicit flanker task and explicit color preference results, a random forest analysis was used to determine the relative importance of factors in the determination of political party affiliation. The blue flanker effect had the largest impact on accurately determining political affiliation. Second most important was the red flanker effect and third was the blue color rating. The red color rating actually decreased the accuracy of the random forest model. These results suggest that political affiliation dynamically changes fundamental perceptual & cognitive processes that are best captured by measures of implicit biases rather than explicit surveys.

Poster Session C > Color, Light and Material: Cognition and preference 1 > Poster C55

Investigating coloration as an emotion expressive cue for social robots

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Social robots are artificial social agents designed to interact with humans across settings, including education, recreation, and healthcare. To be effective, social robots need to communicate social information to humans, such as emotions. Color cues are one promising way to convey emotions because people have rich color-emotion associations that can be leveraged to influence judgments of artificial emotions. In the current work, we generated images of different social robot models (i.e., one that resembles a human face, and one nonanthropomorphic disk that resembles an Alexa) with color differences. Participants indicated how much the color elicited judgments of emotions (anger, disgust, happy, fear, sad, surprise, valence, arousal). Robot colors were sampled across CIELAB color space. Color varied within subjects and robot model varied between-subjects (25 colors x 8 emotions x 2 repetitions = 400 trials). Results for some emotions (e.g., anger) were largely consistent with previous research on human facial color-emotion associations (Thorstenson et al., 2018). For example, both face and disk robots that were redder (a*; B=10.98, p<.001) and yellower (b*; B=8.09, p<.001) were judged as angrier. However, results for other emotions differed between face and disk robots in systematic ways; Emotion judgments for face robots tended to be driven by differences along color-opponent dimensions (a* or b*), while judgments for disk robots tended to be driven by differences along chroma (C*). For example, participants judged face robots as sadder as they increased in blueness (b*, B=-13.06, p<.001), whereas they judged disk robots as sadder when they decreased in chroma (C*, B=-19.86, p<.001) with no effect of blueness (b*, B=-.26, p=.93). These differences can be understood in terms of different emotion-inference processes for different ecological functions. Understanding how people evaluate emotions of robots from coloration will help develop social robots with robust emotion-expressive capabilities, thus facilitating meaningful human-robot social interactions.

Scene Perception: Cognitive processes 1

Poster Session C > Scene Perception: Cognitive processes 1 > Poster C56

Ensemble Perception: Asymmetrical Relationships between Mean, Variability, and Numerosity

View Poster | Play Video | Visit me in Gather.Town Manatee Room on Sunday 4:00 pm - 6:00 pm EDT

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Ensemble perception provides a visual summary of a scene, such as the mean size of a group of objects. The precise mechanisms underlying ensemble perception are still unknown. We tested whether different types of ensemble tasks rely on or compete for shared processes. Perception of the mean requires extracting the similarities across the display, whereas perception of variability requires extracting the differences. We tested whether judging both mean and variability would exert a cost on perceptual sensitivity. An array of circles of different sizes briefly flashed on the screen, and participants (N = 315) judged the mean, variability, and/or numerosity of the display. Participants were less sensitive to mean judgments when also judging the variability. Sensitivity to variability was similar regardless of whether participants also judged the mean. These asymmetrical results suggest that the mean is automatically perceived when judging variability, and thus there is no additional cost to also reporting the mean. However, variability is not automatically perceived when judging the mean, suggesting a cost to also reporting variability. In statistics, calculations of both the mean and the variability require a measure of the number of samples. We explored whether the perception of variability also required perception of the number of samples, in which case, there should be no cost to also judging the number of items. Sensitivity to variability was unaffected when also making a judgment of the number of items. When perceiving variability, judgments of other ensemble properties such as mean and numerosity do not impair variability judgments. In contrast, sensitivity to the mean circle size and numerosity were both impaired when also having to judge variability. Overall, these results show an asymmetrical process underlying ensemble perception, suggesting that ensemble perception could be driven by domain-specific mechanisms dependent on the type of summary statistic computed.

Acknowledgements: National Science Foundation (BCS-1632222 and SES-2030059)

Poster Session C > Scene Perception: Cognitive processes 1 > Poster C57

Ensemble Perception: Perceivers Overestimate Variability by 50-200%

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The visual system efficiently and accurately extracts summary statistics, such as the mean, from sets of similar objects. Evidence for this phenomenon, known as ensemble perception, has been found across numerous features, such as orientation, size, and faces. However, when perceiving variability, the visual system is biased to overestimate variability in ensembles, particularly when objects are more similar and have less variability. This bias is found when perceiving line orientation, size, and hue, suggesting the visual system fundamentally exaggerates the variability in sets of similar objects. To further test this bias, we manipulated the underlying distribution stimuli were drawn from, exposure time, line length, and line contrast. Again, the bias to overestimate variability was found and was larger in magnitude when stimuli were more similar and had less variability. One possible mechanism for this bias is the boundary effect: objects close to a conceptual boundary, such as the same or not, are repulsed away from the boundary. We tested whether the

conceptual boundary of sameness relates only to relevant features (line orientation) or if variation across irrelevant features (line length or contrast) would lessen the bias by pushing the set of stimuli away from the boundary. Participants judged the variability of a set of nine lines presented sequentially by adjusting the variability of nine lines presented simultaneously to match the target stimulus. In all experiments, people were biased to overestimate variability, and the magnitude of the bias was strongest for sets of lines with less variability, regardless of variation in irrelevant factors. The irrelevant feature of line length did not lessen the bias, providing evidence against the idea of a boundary effect related to sameness. If a boundary effect is responsible for the overestimation, the conceptual category is specific to only the relevant feature, not the object as a whole.

Acknowledgements: National Science Foundation (BCS-1632222 and SES-2030059)

Poster Session C > Scene Perception: Cognitive processes 1 > Poster C58

Image- and Task-Based Contributions to Human Object Localization in Natural Scenes

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To investigate object localization in natural scenes, we presented a flickering dot probe in 384 color photographs (100 ms; masked). Participants reported whether the probe was “on” or “off” the object bounded by the nearest border. Object localization sensitivity (d') was > 1.0 (VSS 2019). Now, we compared performance with these masked photographs under three conditions. Participants (1) made a localization judgment only (N = 39), (2) also made an object categorization judgment (N = 48), or (3) made a localization judgment on photographs preceded by one of three intermixed primes: a neutral letter string or a word denoting either the object near the probe or a different object (N = 122; ~40/prime condition). Photograph-based analyses of d' and criterion (c) were conducted for each task. Sensitivity was higher when participants made localization responses only (d' = 1.26) than when they also made categorization judgments or when any prime preceded the photographs, [F(4,1532) = 12.385, p <0.001]; d's in the other conditions did not differ (mean = 1.08). Criterion was biased significantly towards ‘on’ when the prime denoted the nearest object and in condition 2 compared to the other conditions, [F(4,1532) = 66.554, p <0.001]. Thus, task factors affect object localization sensitivity and criterion assessed with briefly exposed photographs of natural scenes. Next, local complexity was indexed as the percentage of pixels on borders within 2° of the border nearest the probe (using canny filter output). Complexity never correlated with d', but in condition (1) and all priming conditions, it correlated significantly with criterion (r’s > 0.165; p’s <0.01): As complexity increased, the bias to respond ‘on’ increased. We consider how attention, object borders, and distinct task requirements contribute to these effects of task and complexity on both object localization sensitivity and participants’ criterion.

Acknowledgements: ONR N00014-16-1-2127

Poster Session C > Scene Perception: Cognitive processes 1 > Poster C59

Oculomotor strategies do not vary under increasing levels of cognitive demand

View Poster | Visit me in Gather.Town Manatee Room on Sunday 4:00 pm - 6:00 pm EDT

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Eye movements can be used as a predictor for various ocular and cognitive conditions. In this study, we propose a new paradigm that can be used to analyze the impact of cognitive load on oculomotor behavior. Participants (N=30) viewed a sequence of 100 scenes freely for 10 seconds. After each scene, they identified a target object from a previous scene among 3 similar distractors from unviewed scenes in a 4 alternative forced choice task. A staircase 2 down 1 up controlled N-back - the number of images back in the sequence from which the target was selected. Our paradigm was successful in actively engaging working memory, as subjects demonstrated more difficulty in recalling correct responses as N-back increased (r(2998)=0.292, p<.001). When comparing the maximum N-back achieved between subjects, there were no significant differences between the number of fixations (F(8,21)=0.848, p=0.572), duration of fixations (F(8,21)=0.693, p=0.694), number of saccades (F(8,21)=0.709, p=0.681), or duration of saccades (F(8,21)=0.279, p=0.966). Similarly, oculomotor behavior did not act as a predictor of correct/incorrect responses with increasing

demand from the N-back task. There was no significant interaction between N-back and response accuracy for the number of fixations ($F(9)=0.128$, $p=0.999$), the duration of fixations ($F(9)=0.385$, $p=0.943$), the number of saccades ($F(9)=0.309$, $p=0.972$), or the duration of saccades ($F(9)=1.350$, $p=0.205$). When analyzing the total area of each scene viewed, we found no significant differences across groups of maximum N-back reached ($F(8)=0.448$, $p=.878$), and proportion of image viewed was not a significant predictor of accuracy ($F(9)=0.803$, $p=0.613$). These results suggest that oculomotor strategies generally do not change as a result of higher cognitive demand.

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Meaning guides clicks like fixations and drives memory for real-world scenes

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Eye-movement data is useful for understanding visual and cognitive processes, but research-grade eye trackers can be cost-prohibitive. Further, the COVID-19 pandemic has made in-person eye-tracking studies impossible. In this study, we collected fixation-like data online by monitoring clicks on real world scene photographs using BubbleView (Kim, Bylinskii, et al., 2017). We sought to predict click locations using meaning maps and to examine the role of attention to meaning in long-term scene memory. [METHOD] Participants were presented with a blurred image for 12s. Whenever the participant clicked on the image, a region of the unmodified scene became visible around their click location. In three experiments, we manipulated the amount of time participants saw each scene before it was blurred (preview: 0, 50, and 200ms). Participants' memory for the scenes was tested at the end of the experiment. [RESULTS] We compared participants' click data from each experiment to previously-collected fixation data for the same scenes and found they were remarkably similar. Participants' click maps correlated strongly with meaning maps (Henderson & Hayes, 2017) and participants were more likely to click high- than low-meaning scene regions, especially with longer scene previews. Finally, we found a significant relationship between participants' clicks on meaningful scene regions and their performance on the memory test. Higher correlations between click maps and meaning maps and higher meaning values at click locations both predicted better memory. [DISCUSSION] Meaning-maps predicted click locations, suggesting click data can be used much like fixation data for studying scene-processing. This result also demonstrates meaning maps' flexibility. We also found a relationship between attention to meaning and long-term memory for scenes, supporting the idea that meaning maps capture the distribution of semantic information in real-world scene images and suggesting that memory for scenes is fueled by semantic information.

Acknowledgements: This work was supported by the NEI of the NIH under award number R01EY027792.

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Scene Inversion Interferes with Meaning-based Guidance in Real-world Scenes

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We have previously shown that meaning is correlated with where people look in scenes across a variety of tasks. To test for a causal relationship between scene meaning and attention we used a scene inversion paradigm. Inverting a scene makes a scene harder to identify and its object properties/relationships more difficult to extract (Kelley, Chun, & Chua, 2003; Epstein et al., 2006). Therefore, scene inversion should make it harder to extract scene meaning and we should observe a weaker meaning-attention association in inverted scenes relative to normally viewed scenes. The present study tested this hypothesis by examining how attention to meaningful scene regions is modulated by viewing real-world scenes from a normal and inverted orientation. Participants' ($N=35$) eye movements were recorded while they viewed 102 real-world scenes for 6 seconds each while performing a scene memorization task. In a within-subjects design, each participant saw half the scenes normally and half the scenes inverted, counterbalanced across participants, and presented in a random order. The spatial distribution of local semantic features for each scene was represented using human ratings of the informativeness of isolated scene patches ('meaning map'; Henderson & Hayes, 2017). We then applied a logistic general linear mixed effects model to examine how a scene region's meaning map value was related to its likelihood of being fixated in the normal and inverted scene conditions, with subject and scene treated as random effects. The results showed a strong dissociation with both an increased likelihood to look at low meaning scene regions

and decreased likelihood to look at high meaning scene regions in the inverted scene condition relative to the normal scene viewing condition. This finding provides evidence for a causal relationship between scene meaning and attention and suggests scene meaning extraction is impaired by non-canonical viewpoints.

Acknowledgements: Supported by the National Science Foundation (NSF) under award number BCS2019445.

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Effects of phonological and visual-spatial working memory load on Boundary Extension.

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Mental expansion of scenes' spatial representation resulting in the memory error referred to as Boundary Extension had been demonstrated using multiple types of tests. People show a consistent tendency to remember having seen a larger expanse of a scene than they actually saw. As there is substantial evident that this robust memory error is a manifestation of underlying processing for spatial layout, it is interesting to examine what effects various concurrent tasks performed while perceiving scenes may have on this processing. In a series of experiments, we compared performance in a control condition, when participants just tried to memorize the scenes, to performance when additional tasks were performed. In these conditions, participants viewed pictures of scenes while performing secondary tasks, such as judging the layout of the scene (hilly/mountainous or flat), searching for people in the scenes, repeating a list of grocery items out loud (verbal task) and describing a list of groceries (verbal+ imagery task). After the initial presentation, participants were presented with versions of the same scenes again, randomly varying the expanse of the scene presented. They were asked to adjust the boundaries of these pictures until the image matched their memory from the original presentation. Replicating prior results with new images, significant boundary extension was obtained in the control condition, when participants simply studied the pictures. The addition of a search task (both for people and mountains) still resulted in Boundary Extension. However, when participants were instructed to also carry out the verbal tasks Boundary Extension was eliminated. Results suggest that, despite the apparent automatic expansion of scene layout, this expansion is affected by high levels of working memory load, including phonological loop load.

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Visual penetration through structured occluders

View Poster | Visit me in Gather.Town Manatee Room on Sunday 4:00 pm - 6:00 pm EDT

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Occluders are prevalent in the visual environment. For example, we need to see through the rain drops on the windshield when driving, or see through the blinds from our living room. Some occluders are random (e.g., rain drops), while others are structured (e.g., blinds). How does occluder pattern influence visual perception? To answer this question, we presented occluded scenes to participants and asked them to judge whether the scene was indoors or outdoors in Experiment 1. The pattern of the occluders was either random or structured (e.g., stripy). The occluders were either chunky (leaving large chunks of the scene visible), or fine-grained (similar to mesh). Scene discrimination was better when the occluders were structured than random but only for fine-grained occluders, and it was identical for structured and random occluders when they were chunky. This suggests that fine-grained structured occluders are more visually penetrable than random occluders. For chunky occluders, the need for visual penetration is reduced due to the large intact scene chunks, which could explain the lack of difference. To see whether this effect is specific to scene perception, we replicated the experiment using object images where participants viewed occluded objects and judged whether the object was animate or inanimate in Experiment 2. The results were highly similar: object discrimination was better when fine-grained occluders were structured than random, but performance was comparable for chunky structured and random occluders. Finally, we extended our findings to numerosity perception where participants estimated the number of objects in an occluded array in Experiment 3. Number estimation was more accurate when fine-grained occluders were structured than random. Therefore, for all three types of perception (scene, object, number) fine-grained structured occluders are more visually penetrable than random occluders. The findings reveal new insights into how visual perception operates with incomplete information.

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Where to draw the line?

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Line drawings, despite their simplicity, capture much of the content of a scene and are sometimes preferred ways of visual communication. They are ubiquitous, from assembly instructions for IKEA furniture and signs prompting customers to wear a mask, to architectural drawings for complex construction projects. But how do people choose where to draw lines, and do they agree with each other? Do the lines drawn by intuition indeed capture the most important scene content? How does artistic training affect what lines people draw? What does the order of the lines drawn tell us about their importance? What physical and spatial features do lines represent? We answer all of these questions in three experiments. In the first experiment, trained artists and non-artists made multiple drawings of a small set of complex real-world scenes by tracing contours on a digital tablet. In the second experiment, independent observers ranked the drawings of the same scene by how representative they are of the original photograph. Overall, artists' drawings ranked higher than non-artists'. Matching contours between drawings of the same scene revealed that the most consistently drawn contours tend to be drawn earlier. We generated half-images with the most- versus least-consistently drawn contours by sorting contours by their consistency scores. In a third experiment, observers performed significantly better at fast scene categorization for the most compared to the least consistent half-images. The most consistently drawn contours were on average longer and more likely to depict occlusion boundaries, whereas the least consistently drawn contours frequently depicted surface normals. Using psychophysics experiments and computational analysis, we confirmed quantitatively what makes certain contours in line drawings special: longer contours mark occlusion boundaries and aid rapid scene recognition. They allow artist and non-artists to convey important information starting from the first few strokes in their drawing process.

Acknowledgements: NSERC Discovery grant to DBW

Poster Session C > Scene Perception: Cognitive processes 1 > Poster C65

Tangled Physics: Knots as a challenge for physical scene understanding

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A resurgence of interest in intuitive physics has revealed a remarkable capacity in humans to make common-sense predictions about the unfolding of physical scenes. For example, recent work has shown that observers can correctly judge properties such as stability, weight distribution, gravity and collision physics, especially in rich naturalistic images. These results have suggested that physical scene understanding recruits a general-purpose “physics engine” that reliably simulates how scenes will unfold. Here, we complicate this picture by introducing knots to the study of intuitive physics. Knots are naturalistic stimuli that appear across cultures and time periods, and are widely used in both mundane scenarios (e.g., closing a bag or tying one's shoes) and more technical applications (e.g., securing a boat or even supporting a rock-climber). Yet, here we show that even basic judgments about knots strain human physical reasoning. Observers viewed photographs of simple “bends” (i.e., knots joining two lengths of string) that share strong visual similarity but greatly differ in structural integrity. For example, observers saw not only “reef” knots (a common knot used for millennia), but also “thief” knots (which differ only in the position of a single strand but are significantly less secure than “reefs”), along with “granny” and “grief” knots (which share a similar relationship). In a two-alternative forced-choice task, observers judged each knot's stability relative to every other knot. Strikingly, observers reliably ranked weaker knots as strong and stronger knots as weak, both across knot-families (e.g., incorrectly judging granny knots as stronger than reef knots) and within a given family (e.g., failing to judge “thiefs” as weaker than “reefs”). These failures challenge a general-purpose “physics engine” hypothesis, and perhaps suggest that knots and other examples of soft-body physics recruit different cognitive processes than rigid-body physics.

Acknowledgements: This work was funded by NSF BCS #2021053 awarded to C.F

Poster Session C > Scene Perception: Cognitive processes 1 > Poster C66

Selective processing of social interactions during naturalistic movie viewing

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The ability to recognize interactions between two or more people in a complex visual scene is a crucial skill that helps us navigate the social world. Previous studies have revealed that the brain selectively represents others' social interactions in the posterior superior temporal sulcus (pSTS). These studies, however, have all relied on simple artificial stimuli. It is unclear to what extent social interaction selectivity exists in the real world where social interactions co-vary with many other sensory and social features (such as faces, voices, theory of mind). To address this, a few studies have adopted a naturalist movie viewing paradigm, but none have looked at the unique variance explained by social interactions beyond that explained by other covarying features in natural movies. The current study utilizes machine learning-based fMRI analyses and computer vision techniques to uncover the brain mechanisms uniquely underlying naturalistic social interaction perception. We analyzed two publicly available fMRI datasets, collected while participants watched two different commercial movies in the MRI scanner. By performing voxel-wise encoding and variance partitioning analyses, we demonstrate that a socio-affective model (a linear combination of an agent speaking, social interactions, theory of mind, perceived valence, and arousal) independently contribute to predicting brain responses in the STS and the dorsal medial prefrontal cortex. Importantly, the STS and the precuneus show unique selectivity for scenes that contain social interactions, even after the effects of all other visual and social features, including the presence of faces and theory of mind, have been controlled for. This selectivity generalized across both sets of movie data despite the fact that data came from different genres, subjects, and labs. Together, these findings suggest that social interaction perception recruits dedicated neural circuits during natural viewing and is an essential dimension of social understanding.

Attention: Divided, models, objects and cues

Poster Session C > Attention: Divided, models, objects and cues > Poster C81

Attentional dynamics during multiple object tracking are explained at subsecond resolution by a new 'hypothesis-driven adaptive computation' framework

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A tremendous amount of work on visual attention has helped to characterize *what* we attend to, but has focused less on precisely *how* and *why* attention is allocated to dynamic scenes across time. Nowhere is this contrast more apparent than in multiple object tracking (MOT). Hundreds of papers have explored MOT as a paradigmatic example of selective attention, in part because it so well captures attention as a dynamic process. It is especially ironic, then, that nearly all of this work reduces each MOT trial to a single value (i.e. the number of targets successfully tracked) -- when in reality, each MOT trial presents an experiment unto itself, with constantly shifting attention over time. Here we seek to capture this dynamic ebb and flow of attention at a subsecond resolution, both empirically and computationally. Empirically, observers completed MOT trials during which they also had to detect sporadic momentary probes, as a measure of the moment-by-moment degree of attention being allocated to each object. Computationally, we characterize (for the first time, to our knowledge) an algorithmic architecture of just how and why such dynamic attentional shifts occur. To do so, we introduce a new 'hypothesis driven adaptive computation' model. Whereas previous models employed many MOT-specific assumptions, this new approach generalizes to any task-driven context. It provides a unified account of attention as the dynamic allocation of computing resources, based on task-driven hypotheses about the properties (e.g. location, target status) of each object. Here, this framework was able to explain the observed probe detection performance measured at a subsecond resolution, independent of general spatial factors (such as the proximity of each probe to the MOT targets' centroid). This case study provides a new way to think about attention and how it interfaces with perception in terms of rational resource allocation.

Poster Session C > Attention: Divided, models, objects and cues > Poster C82

Behavioral benefits of spatial attention explained by multiplicative gain, not

receptive field shifts, in a neural network model.

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Spatial attention in humans and animals has been found to correlate with gain changes as well as with shifts in location and size of receptive fields in early visual cortex. But which, if any, of these physiological effects can account for the behavioral benefits of attention? Here we show in a computational model that changes in receptive field location and size are consequences of applying multiplicative gain and that they are not required for the behavioral benefits of attention. Instead, gain alone causes attended regions to have a larger impact on decision making. We asked human observers and a neural network model of the ventral visual stream to detect whether or not an object of a given category was present in a grid of four images. On focal attention trials, human observers were informed by a cue that the target could appear only at one location, improving performance. We found that applying Gaussian gain at the cued location in the early layers of the neural network model could mimic this cued performance improvement. Gain also caused receptive fields of later layers to decrease in size and shift towards the cued location. Through mechanistic models designed to isolate the behavioral consequences of each effect separately, we found that a gain applied early in the network increases the effective weight of the attended region at the last stage of the network, entirely explaining the behavioral benefits. In contrast, receptive field size and location changes in the absence of a gain component did not improve task performance. Our findings suggest that changes in receptive fields are epiphenomenal, unrelated to the causal changes that lead to behavioral improvement during directed spatial attention.

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Poster Session C > Attention: Divided, models, objects and cues > Poster C83

Investigating the Role of Cognitive Control in Aesthetic Judgments

View Poster | Visit me in Gather.Town Dolphin Room on Sunday 4:00 pm - 6:00 pm EDT

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Aesthetic judgments dominate much of daily life by guiding how we evaluate objects, people and experiences in our environment. Neuroaesthetics is a fledgling field of research that aims to study the neurobiology of aesthetic judgments. One modestly studied aspect of neuroaesthetics is the extent to which automatic versus controlled processing is involved in aesthetic judgments. The study of automaticity is important because it can provide real insight into the structure of underlying cognitive systems, as well as how they differ across different domains, such as between aesthetic and non-aesthetic contexts. The current pre-registered study aimed to examine whether a central cognitive load produces greater reaction time interference on aesthetic judgments relative to non-aesthetic judgments. Ninety-two participants completed both aesthetic and implied motion judgments using a 2-alternative forced choice on paintings describing people or landscape, whilst holding in memory a single letter (low load) or six letters (high load). The results showed an effect of load type on reaction time, such that high load increased response times compared to low load. However, there was no interaction between the load type and the judgment type; instead, the confidence intervals for reaction time interference were almost entirely overlapping between judgments types. Contrary to dominant models in the literature, these findings suggest that aesthetic and non-aesthetic judgments rely on a similar degree on automatic versus controlled processing and the operations of the central executive. Future studies will be required to probe the extent to which such similarities generalise to other types of aesthetic judgments.

Acknowledgements: ESRC Wales Doctoral Training Partnership

Poster Session C > Attention: Divided, models, objects and cues > Poster C84

Hemifield effects on divided attention for dual tasks with visual objects

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Recent studies have shown a surprising hemifield effect in multiple object tracking: one can track twice as many objects in different hemifields as in a single hemifield. No such effect occurs in typical visual search tasks, but it has been reported in "multifocal" visual search, in which only some areas of the visual field are relevant. One hypothesis is that hemifield effects are specific to tasks requiring multifocal spatial attention (Alvarez, Gill, & Cavanagh, 2012, JOV). To test this hypothesis, we conducted a dual-task experiment in which observers made semantic categorizations of nameable objects. This divided attention paradigm requires multifocal spatial attention because there are separate foci for the two tasks. For each task, one must attend the task-relevant stimulus and ignore the other stimuli. Previous studies using a dual-task paradigm have shown large divided attention effects for object judgments, measured as the dual-task deficit (the difference in performance in single- and dual-task trials). In our experiment, 4 objects were presented simultaneously in separate quadrants, and participants made judgments about 1 of 4 objects (single-task trials) or 2 of 4 objects (dual-task trials). As in previous studies, there was a large dual-task deficit for object judgments. To address hemifield effects, the dual-task deficit for a unilateral condition with relevant objects within the same hemifield was compared to the dual-task deficit for a bilateral condition with relevant objects in separate hemifields. Preliminary results showed no difference in the dual-task deficits for unilateral and bilateral conditions. Unlike multiple object tracking, dual tasks revealed little or no hemifield effects for divided attention to multiple objects. These findings are not consistent with the hypothesis that such effects are specific to tasks with multifocal spatial attention.

Acknowledgements: This work was supported in part by NIH NEI grant F32-EY030320 to DVP.

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Inopportune Warning Cues Benefit Only Some Participants in a Poser Cueing Task

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In Posner’s (1980) classic study, he showed people can use peripheral cues to more quickly attend beyond where they are looking (covert attention). The standard Posner cueing paradigm presents isolated stimuli but the everyday world is dynamic, full of potential distractors, and information can appear at inopportune times. We assessed people’s use of a peripheral cue (a warning dot) that appeared while participants were engaged with a primary target discrimination task. The warning dot was highly predictive and indicated the location of the target on the NEXT trial but, when it appeared, it was irrelevant to the current task. Although we told participants the purpose of the warning dot and told them to use it to the best of their abilities, we found only about half of the participants said they used it. Both warning users and non-users experienced a disruption in current target processing but only warning users showed a facilitatory impact of warning validity on target processing on the next trial. Many non-warning users indicated they thought the warning dot was a distraction, or was inaccurate and disregarded it. These findings suggest that peripheral signals capture attention even when engaged with a primary task but the impact on later task performance is not uniform between people. In the everyday world, covert attention and the use of peripheral warnings may be less useful than once implied by Posner cueing paradigms and may only lead to distraction for some people.

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Effects of task-relevant, and -irrelevant competition on attentional cuing and visual search

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According to the biased competition theory, multiple stimuli compete to be represented in the visual system. Attention is a way to resolve this competition. This competition is enhanced when stimulus heterogeneity increases. Hence, we hypothesized that the effect of attention increased under the high level of competition between multiple, heterogenous stimuli. To test this, we measured the effect of spatial attentional cue either when a target stimulus (tilted Gabor grating) was presented by itself or when the target was accompanied by multiple distractors (vertical grating). Importantly, we manipulated stimulus homogeneity/heterogeneity by the varying spatial frequency of the stimuli. With the heterogenous trials, the spatial frequencies of each stimulus were different, while all the stimuli had the same spatial frequency in the homogeneous trials. Notably, given that the target was distinguished by its orientation, the spatial frequency of the stimuli was irrelevant to the task. The target and distractors were preceded by a salient, peripheral cue. The results showed that the cuing effect significantly increased under distractor-interference. However, in the presence of multiple stimuli, stimulus heterogeneity did not affect the magnitude of cuing effect. In the follow-up experiment, we further varied the number of stimuli, such that the target stimulus was presented by itself or it was accompanied by a variable number of distractors (1, 3, 7). This experiment showed that the efficiency of target searching was significantly impaired when multiple, heterogeneous stimuli were presented. Still, the magnitude of cuing effect was not affected by the stimulus heterogeneity. Taken together, the stimulus heterogeneity in a task-irrelevant dimension seems to have dissociable effects in attentional cuing effect and search efficiency. Presumably, multiple heterogenous stimuli suppress each other to greater extent than homogeneous stimuli, lowering search efficiency. However, this increased competition does not necessarily affect the effect of attentional cue.

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Neural Correlates of Object-Based Attention in Early Visual Cortex in a 100% Valid Exogenous Cuing Task

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A number of studies have examined whether the statistical imbalance of target frequency in the two-rectangle paradigm drives prioritization in object-based attention (OBA). While results suggest that OBA effects can be driven by spatial probability, behavioral measures are limited to the inclusion of invalid trials and it is yet unknown whether OBA would be observed in a condition where the cue is presented at 100% validity. To investigate this, we leveraged the spatial specificity of fMRI and the retinotopic organization of early visual cortex to identify potential neural correlates of OBA in the complete absence of invalid trials. Using fMRI, we had nine participants perform an exogenous version of the classic two-rectangle OBA paradigm while simultaneously measuring changes in BOLD signals arising from retinotopically organized cortical areas V1, V2 and V3. In the first half of the experiment, the exogenous cue was 100% valid. In the second half, the cue was 83.3% valid, more closely matching standard OBA paradigms. We then sorted BOLD signals arising from quadrant-based regions of interest according to whether they corresponded to cued, uncued same object or uncued other object. Results: in both the 100% and 83.3% runs we compared cued and uncued responses and as expected observed effects of spatial attention (cued versus uncued) in V2 and V3 but not V1. We also observed small but statistically significant effects of OBA in V3 (but not V2 and V1) in both the 100% and 83.3% valid runs. Moreover, the effects of OBA were no smaller in the 100% compared to 83.3% valid runs. Conclusions: Neural correlates of OBA can be observed using exogenous cueing and in the absence of invalid trials. This suggests that while target-location frequency may influence the distribution of cued attention, at least some OBA enhancement can arise independently of target uncertainty.

Acknowledgements: NSF 1632738 & NSF 1632849

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Neural reconstructions of task-relevant and irrelevant features of attended objects

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Visual attention plays an essential role in selecting task-relevant and ignoring task-irrelevant information, for both object features and their locations. In the real world, multiple objects with multiple features are often simultaneously present in a scene. When spatial attention selects an object, how are the task-relevant and task-irrelevant features represented in the brain? Previous literature has shown conflicting results on whether and how irrelevant features are represented in visual cortex. In an fMRI task, we used a modified inverted encoding model (IEM, e.g., Sprague & Serences, 2015) to test whether we can reconstruct the task-relevant and task-irrelevant features of spatially attended objects in a multi-

feature (color + orientation), multi-item display. Subjects were briefly shown an array of three colored, oriented gratings. Subjects were instructed as to which feature (color or orientation) was relevant before each block, and on each trial were asked to report the task-relevant feature of the object that appeared at a spatially pre-cued location, using a continuous color or orientation wheel. By applying a standard IEM, we achieved reliable feature reconstructions for the task-relevant features of the attended object from visual ROIs (V1 and V4v). Modifications to the IEM procedure produced reconstructions of variable quality for the task-irrelevant features in visual ROIs. Preliminary searchlight analyses also showed that task-irrelevant features of attended objects could be reconstructed from activity in some intraparietal areas. These results suggest that both relevant and irrelevant features may be represented in visual and parietal cortex but in different forms. Our method provides potential tools to noninvasively measure unattended feature representations and probe the extent to which spatial attention acts as a “glue” to bind task-relevant and task-irrelevant features.

Acknowledgements: NIH R01-EY025648 (JG), NSF 1848939 (JG)

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Frontal-plane distance judgments between two equal-size items are made on the basis of a salience map

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We hypothesize that distance judgments between two items in the frontal plane are made on the basis of information recorded in a salience map that registers only salience and not the features that produced the salience. In terms of the number of neurons required for distance judgments, this would be an extremely economical solution. To test this hypothesis, we presented subjects with stimuli containing two target disks for 200 msec followed immediately by an effective random masking field. The target disks were separated by center-to-center distances varying from 1.52 to 20.83 cm (1.49 to 20.21 deg). Three subjects estimated target separation in tenths of inches. Subjects were trained until there was no further improvement and then given complete feedback after each of 1,453-1,463 test trials. The critical aspects were the composition of the background (either filled with 142 distracter disks equal in size to target disks but of various shades of gray to conceal targets, or plain gray backgrounds to maximally expose targets). Target disks were either maximally black or white, purple, gratings of different orientations, or outline circles. The gratings and color could not be discriminated from the background by luminance, only by being different from their neighbors in some important dimension, i.e.., salience. Five pairs of identical targets and 7 pairs of different targets were tested on the 142-distracters background, one different-targets pair and two identical-targets pairs were tested on the plain gray background (easiest possible conditions). Simple result: For all subjects, judged distance accuracy was statistically equivalent for all 15 pairs. Once the two target disks were identifiable, being of identical composition or being easily discriminable from the background offered zero advantage for judged distance accuracy. Conclusion: Frontal plane distance judgments are made on the basis of a salience map.

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Quantifying the effects of feature similarity on attentional selection using psychophysical scaling

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The similarity between target and distractor features is a main factor determining the efficiency of attentional selection. Prior studies investigating the impact of target-distractor similarity on performance have mostly selected similarity levels in a categorical and qualitative way (e.g., by using discrete color or shape categories), or have used distance in physical stimulus space to quantify similarity. However, findings from psychophysics have shown that the physical stimulus space does not map linearly to psychological similarity. Thus, we here assessed psychological similarity using psychophysical scaling methods and tested how these similarity functions relate to attentional selection. We measured psychological similarity of colors chosen from CIELab space as a test case. Then, using a standard visual search task, we measured search times using a wide range of target-distractor similarity levels (Exp. 1) and also manipulated the number of distractors (2 or 7) to measure search efficiency (Exp. 2-3). In another sustained attention task (Exp. 4), participants

continuously monitored a set of target dots among distractor dots to detect brief changes in luminance, and the color similarity between target and distractor dots was manipulated across trials, as in the visual search tasks. We found that performance in both tasks was comparably affected by target-distractor similarity, with search RTs and luminance discriminability plateauing at approximately 40°-50° around the CIELab color wheel. In contrast, the number of visual search distractors only affected performance when similarity was very high (below 20°). Interestingly, performance in each task was non-linearly related to both the physical and psychological similarity between targets and distractors. Overall, these findings suggest that there is no simple linear relationship between feature similarity and attentional selection, and point to the importance of understanding how the underlying perceptual organization of a given feature space interacts with mechanisms of attentional selection.

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An improved method for evaluating inverted encoding models

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Inverted encoding models (IEMs) have recently become popular as a method for decoding stimuli, notably used to reconstruct perceptual and mnemonic visual features (e.g., Brouwer & Heeger, 2009; Sprague, Ester, & Serences, 2016). We demonstrate that current evaluations of IEMs could produce spurious conclusions because of a failure to account for underlying channel response profiles (basis set) of the encoder. Our novel modification to IEMs solves this problem and further leads to improved decoding interpretability and the capacity for trial-by-trial goodness-of-fits. The advantages of IEMs are that the model is based on population-level tuning functions (aka channel response profiles), which is thought to better reflect underlying neuronal tuning than similar decoding models, and that decoding with IEMs occurs on a continuous scale such that stimuli not used to train the model may be predicted. We argue that IEMs remain a powerful method to detect stimulus-specific information, however, the means by which IEMs are currently evaluated is problematic. Currently, IEMs are measured via reconstructed channel response profiles (“reconstructions”) which are averaged and aligned across trials. Using simulations and fMRI data from studies of visual perception and attention, we show that the standard measures for evaluating reconstructions (e.g., slope, amplitude, bandwidth) do not take into account the assumed channel response profiles of the encoder. This is important because a significantly steeper slope may not necessarily imply more stimulus-specific information in the brain region. That is, a reconstruction that “looks” better (e.g., higher amplitude, lower standard deviation) can sometimes reflect less stimulus-specific information than a relatively worse-looking reconstruction (even if the reconstructions come from the same basis set). Our method solves these problems and additionally provides a means for improved decoding interpretability (reconstructions in stimulus space rather than channel space) and trial-by-trial goodness-of-fit estimates (useful for excluding noisy trials to increase statistical power).

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Successfully withholding attention shifts is strongly modulated by shift/hold cue ratio

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Visual attention allows one to voluntarily orient the focus of their attentional spotlight toward behaviorally relevant information. Many fMRI studies have shown that the medial superior parietal lobule (mSPL) robustly increases activation when subjects are cued to shift attention. However, when cued to hold attention, mSPL shows a well-defined, small-amplitude BOLD response increase, suggesting that mSPL may perform computations of cue interpretation, rather than exclusively attention shifting. We investigated this alternative using a behavioral attention task involving two target RSVP streams (one in each hemifield), each flanked by three distractor RSVP streams. Cues (red letters embedded within a homogeneously white letter stream) instructed participants to Shift or Hold their attention on the current stream. Participants discriminated the parity of target digits via button press. Simultaneously, a nontarget digit was either absent

(50% of trials) or present in the opposite stream: either congruent (25%) or incongruent (25%) with target identity. Critically, three subject groups experienced different proportions of Shift/Hold trials (70%/30%, 50%/50%, 30%/70%). Experiments in which Hold trials are more prevalent have not previously been conducted. During Hold trials, if mSPL activation simply reflects cue interpretation, we would predict no effect of nontarget congruency; however, if mSPL reflects a brief erroneous attention shift, performance could be affected by the nontarget in the noncued stream. We observed a statistically significant nontarget congruency effect during Hold trials in the 70/30 condition (when most trials cued a Shift) and 50/50 condition, but not in the 30/70 condition (when most trials cued a Hold). We saw this across two cue-target intervals (212ms and 318ms). Thus, our results suggest that the BOLD increase observed in mSPL following a Hold cue may not reflect cue interpretation, but rather a brief shift of attention encouraged by the large proportion of shift cues commonly used in these experiments.

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Both cue directionality and mental perspective contribute to social attention

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Research showing that visual perspective of others spontaneously interferes with our own has led to a stimulating debate about whether social attention effects are driven by the directionality of agent’s social cues, the perceived content of their minds, or both. Here, we use a novel task to dissociate the contributions of these two variables. Participants viewed an image of an avatar (N=51) or an arrow (N=57) at fixation. From their own perspective, participants located a peripheral target (number 8) that was presented with a distractor at an opposing location. The cue pointed at the target or at the distractor equally often. Further, the cue’s and the participants’ mental content either matched or mismatched depending on whether the cue indicated the target or the distractor. Replicating past work showing the typical effects of cue directionality, participants were overall faster to respond to targets when central cues pointed at the target. However, their responses were additionally facilitated when the perspective content matched relative to when it mismatched irrespective of cue type. As such, these results suggest that both cue directionality and mental content contribute to social attention and raise additional questions about the specific contributions of agency with social and non-social cues.

Acknowledgements: NSERC, SSHRC, William Dawson fund

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Examining External and Internal Attentional Breadths

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Selecting objects for further processing is critical for producing appropriate goal-directed behaviours. The external and internal attentional framework emphasizes the targets of attention. Specifically, attention can be directed to either objects immediately present in the visual field, or to internal object representations held in memory. Our research provides the first in-depth investigation into how the breadths (narrow/broad) of internal and external attention interact. In Experiment 1, we tested whether manipulating internal attentional breadth impacts external attentional selection. Specifically, we examined if a narrow internal attentional breadth decreases interference by external flankers located outside this internal window. In each trial, a three-colour working memory array was presented. This array was either narrow (smaller items placed closely together) or broad (larger items placed further apart) to manipulate internal breadth. Then, to measure external attention, a flanker task was presented where target arrows were flanked by response compatible or incompatible distractor arrows. Finally, a change detection probe was displayed to test for colour memory. Results showed that narrow internal attention resulted in decreased flanker interference effects relative to when internal attention was broad. In Experiment 2, we tested whether external attentional breadth impacts internal attentional breadth, to determine whether their relationship is bidirectional. This was done by switching the order of the tasks; after first responding to the flanker target, a three-colour working memory array was presented, followed by a change detection probe. We did not observe any effect of external attentional breadth on working memory performance. Our research suggests that while external attentional breadth influences internal attentional breadth, this process is not necessarily bidirectional.

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Gazing to look vs. gazing to think: Gaze cueing is modulated by the perception of others' external vs. internal attention

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What we see depends on where we look, and where we look is often influenced by where others are looking. In particular, when we see another person turn to look in a new direction, we automatically follow their gaze and attend in the same direction -- a phenomenon known as gaze cueing. This reflexive reorienting is adaptive, since people usually shift their gaze to *look* toward the objects or locations they are attending to. But not always: Sometimes people shift their gaze to *think*, as when they look up and away while retrieving information from memory or solving a difficult problem. Such gazes are not directed at any particular external location, but rather signal disengagement from the external world to aid internal focus. Is gaze cueing sophisticated enough to be sensitive to others' (external vs. internal) focus of attention? To find out, we had observers view videos of an actress who is initially looking forward. She is then asked a question, and before responding she looks upward and to the side. The questions themselves concerned either an external stimulus ("Who painted that piece of art on the wall over there?") or an internal memory ("Who painted that piece of art we saw in the museum?"). Despite using identical videos (differing only in their audio tracks), gazes preceded by the 'external' (vs. 'internal') questions elicited far stronger gaze cueing, as measured by the ability to identify a briefly flashed symbol in the direction of the gaze. This effect replicated in multiple samples, and with multiple pairs of 'external' vs. 'internal' questions. This shows how gaze cueing is surprisingly 'smart', and is not simply a brute reflex triggered by others' eye and head movements. And perhaps more importantly, it demonstrates how perception constructs a rich and flexible model of others' attentional states.

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Comparing Human and AI Attention in Visuomotor Tasks

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Deep reinforcement learning (RL) is a powerful machine learning tool to train AIs to solve visuomotor tasks. Recently these algorithms have achieved human-level performance in tasks such as video games. However, the trained models are often difficult to interpret, because they are represented as deep neural networks that map raw pixel inputs directly to decisions. It is hence unclear whether AIs and humans solve these tasks in similar or different ways, and why AIs and humans perform relatively well or poorly in certain tasks. To understand human visuomotor behaviors in Atari video games, Zhang et al. (2020) collected a dataset of human eye-tracking and decision-making data. Meanwhile, Greydanus et al. (2018) proposed a method to interpret deep RL agents by visualizing the “attention” of RL agents in the form of saliency maps. Combining these two works allows us to shed light on the inner workings of RL agents by analyzing the pixels that they attend to during task execution and comparing them with the pixels attended to by humans. We ask: 1) How similar are the visual features learned by RL agents and humans when performing the same tasks? 2) How do similarities and differences in these learned features correlate with RL agents' performance? We show how the attention of RL agents develops and becomes more human-like during the learning process, as well as how varying the parameters of reward function affects the learned attention. Additionally, compared to humans, RL agents still make simple mistakes in perception (e.g., failing to attend to important objects), and generalize poorly to unfamiliar situations. The insights provided have the potential to inform novel algorithms for closing the performance gap between RL agents and human experts. They also indicate the relative advantages and disadvantages of humans, compared to AIs, in performing these visuomotor tasks.

Acknowledgements: NIH EY05729

Binocular Vision: Stereopsis

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Stereopsis and Distance Representation for Action in Pictorial Space

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While an impression of 3D space is attainable through binocular viewing of pictorial scenes, monocular viewing through an aperture of the same scenes provides a stronger sensation of depth and negative space; objects feel more tangible and real. We had observers actually reach into pictorial spaces under both binocular-aperture and monocular-aperture viewing conditions. We created 3D landscape scenes with varied depth separation, and marked different points in the scenes with colored dot targets. Images of these scenes were presented to observers at two different distances using a mirror reflection system. These images were scaled so that they would have the same retinal size. We asked observers to reach out and “touch” the points in space where they perceived the target dots to be with intermixed viewing and distance conditions. We measured the 3D point in space of their finger tip at the end of each reach movement. Importantly, we found that, under the binocular condition, the observers depth judgments were primarily based on the image distance, while in the monocular condition, their responses were modulated by the pictorial depth in the scenes instead of the image distance. These pictorial depths were similar in both distance conditions, indicating that observers perceived a consistent pictorial space in the monocular condition. Monocular-aperture viewing of pictorial scenes thus does provide a stronger sensation of depth which can be explored by motor actions.

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Binocular contrast perception of gratings, noise, and natural images

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The visual system is tasked with combining the two eye’s views into a single percept of the world. To understand the principles that underlie this combination, dichoptic stimuli (stimuli that have different levels of luminance and/or contrast in the two eyes) can be used to probe how each eye’s input contributes to the ultimate binocular percept. For example, contrast perception of simple dichoptic stimuli, such as sine wave gratings, is well-predicted as a weighted combination of the two eyes inputs typically biased towards the eye seeing higher contrast. We aimed to examine contrast perception of more complex dichoptic stimuli to determine how higher-order visual properties may influence the binocular percept. Using a perceptual matching task in which participants adjusted one stimulus (which was non-dichoptic) to match the perceived contrast of another stimulus (which was dichoptic), we examined the perceived contrast of three classes of stimuli: gratings, 1/f noise, and natural image patches. In addition to finding the closest perceptual match, we also asked participants to report on whether and how the two stimuli differed in appearance. We found that: 1) Spatial variation in the stimuli modulated binocular contrast perception; however, the effect depended on the stimulus type. Specifically, spatial manipulations that affected the perceptual matches for gratings (i.e., increasing or decreasing the contrast of the surrounding area in either eye) did not have a systematic effect on the matches for the noise and natural images. 2) Across all stimulus types, however, spatial manipulations did affect the proportion of trials in which participants reported finding an “exact match”. These results suggest that spatial frequency interactions and higher-level inferences can modulate both the interocular weighting and the perceptual interpretation during binocular combination.

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Differences in contrast tuning for absolute and relative disparity channels

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The visual system is comprised of several binocular subsystems, at least two of which compute estimates of absolute and relative disparities. Absolute disparities are extracted at early stages of processing, whilst relative disparities may be computed by differencing the outputs of two or more absolute disparity detectors. A prediction of a simple differencing model is that the contrast dependence of absolute and relative disparity coding should be the same. We tested this prediction by recording steady-state visual evoked potentials (N=7) to stimuli designed to isolate disparity and by measuring response components associated with absolute vs relative disparity processing. Stimuli were dynamic random-dot stereograms alternating at 2Hz between a disparate surface and a zero-disparity plane. Disparity amplitude was swept, increasing the depth modulation over the course of each 10-second trial. Stimuli were shown at 8 log-spaced contrast levels ranging from 2.5-80% Michelson contrast. Disparate stimuli either contained only absolute disparities (a flat plane with no references) or relative disparities (a corrugated surface at 0.75 cpd). We replicated earlier results showing that the sustained 1f1 response best captures relative disparity processing, whilst the transient 2f1 response is largely driven by absolute disparities, suggesting a division of labour across different temporal channels. The 1f1 response showed a steeper contrast gain, implying that the sustained, relative disparity channel is more dependent on stimulus contrast. The absolute disparity response could be driven by lower contrast levels: At low stimulus contrasts, the absolute disparity signal was greater, with relative disparity catching up and overtaking in amplitude from about 10% contrast. Our results suggest differences in the contrast dependency of absolute/transient and relative/sustained disparity mechanisms that are inconsistent with a simple differencing computation. The differential sensitivity of these two disparity sub-systems may have implications for the development of disparity mechanisms, as well as clinical interventions in amblyopia.

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Poster Session C > Binocular Vision: Stereopsis > Poster C100

Vergence accuracy and precision are degraded by fusion lock eccentricity

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Disparity is an efficient and readily available cue for estimating the position in depth of our surroundings and objects of interest. It is also essential for successfully converging our eyes. While a great deal is known about disparity inputs to perception, we aimed here to determine the efficacy of disparity information from different parts of the visual field in driving vergence. Is disparity information equally effective across the visual field? We used a psychophysical approach to investigate the quality of vergence and binocular fusion for different eccentricities. Participants viewed dichoptic pairs of nonius lines, surrounded by binocular fusion locks consisting of annular sectors to drive vergence and binocular fusion. We manipulated the disparity of the fusion locks, effectively varying the vergence load of the task. We also manipulated the fusion lock eccentricity while compensating its size to account for cortical magnification. Participants aligned the centrally-positioned nonius lines in an adjustment task. The relative offset of the two lines was used as a readout for vergence accuracy and precision. We then computed vergence errors by subtracting each nonius offset from the fusion lock disparity. We show that the eccentricity at which the fusion lock stimuli are presented degrades vergence accuracy as well as precision: with fusion locks presented centrally at about 1 degree we observed the smallest vergence errors across all disparities. Moving the fusion lock to the periphery impaired vergence, resulting in significantly higher errors across disparities. Interestingly, the stability of the vergence drive also seems to be affected, with higher variability in the vergence errors observed at higher eccentricities. Similar to the strong bias towards central vision for the perception of disparity, our results quantify a similar bias for vergence control.

Acknowledgements: Grant n. EY018875 from the National Eye Institute, National Institutes of Health to A. M. N.

Poster Session C > Binocular Vision: Stereopsis > Poster C101

The impact of spherical defocus on diplopia and vergence

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Children with anisometropia (unequal refractive error in the two eyes) are at risk of atypical binocular development. To assess the potential impact of anisometropia on eye movements and perception, we compared the effects of unilateral vs. bilateral spherical defocus on reflexive vergence and perception of single vision. Adults (N=9, 15-51 yrs) and typically developing children (N=4, 7-10 yrs) viewed a dichoptic cartoon (2deg x 3deg) displayed on a grey background. A step change in disparity ranging from 0 to 8deg was introduced for 320ms, followed by a blank screen. Vergence responses were recorded with an Eyelink 1000 and subjects reported whether they perceived the target to be single or diplopic. Spherical defocus ranging from 0.5 to 4D was applied to one or both eyes' stimuli using convolution of the Point Spread Function for the subject's pupil size. Six repetitions were presented in random order. Open loop vergence amplitude, at the end of the second latency period, was used to estimate the response (without feedback). The diplopia threshold was defined as the 63% point on a Weibull function fit to the perceptual data. On average across all participants, in the absence of defocus, open loop vergence peaked at +/-1.25deg disparity with amplitudes of 0.33±0.24deg convergence and -0.41±0.25deg divergence. For adults, bilateral defocus had no effect on this reflex portion of the response, as 4D of defocus resulted in 0.28±0.42deg and -0.40±0.30deg amplitudes. Unilateral defocus of 4D reduced amplitudes to 0.14±0.28 and -0.25±0.20deg. The mean adult diplopia threshold increased significantly from 1.28±0.51deg with no defocus to 1.71±0.62deg when 4D bilateral defocus was applied, but decreased to 0.89±0.27deg when the 4D defocus was unilateral. Reflex vergence responses were made to all of these small central stimuli. In adults, although bilateral defocus appeared protective against diplopia, anisometropia tended to disrupt both vergence and perception.

Acknowledgements: NEI: R01 EY014460 (TRC), P30 EY019008

Poster Session C > Binocular Vision: Stereopsis > Poster C102

Predicting residual stereopsis in macular degeneration

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Individuals with macular degeneration typically lose vision in the central region of one or both eyes. A binocular scotoma occurs when vision loss occurs at overlapping locations in both eyes, but stereopsis is impacted when the visual field in either eye is affected. Here we map the periphery with local disparity stimuli to determine how locations with functional stereopsis relate to the scotomata in the two eyes. Participants included those with monocular (N=4) or binocular (N=6) scotomata and age-matched controls (N=5) with healthy vision. We used a novel stereo-perimetry protocol to measure local stereopsis across the visual field (up to 25° eccentricity). Targets (with or without depth information) were presented on a random dot background. Depth targets had true binocular disparity of 20' (crossed), whereas non-depth targets were defined by monocular cues such as contrast and dot density. The target was a 1° square region at the fovea and was m-scaled with eccentricity. Participants viewed the display binocularly and were asked to maintain fixation during target presentation. During the response interval, participants (i) reported the location of the target, and (ii) indicated whether it was in depth or flat. Depth sensitivity (d') estimates from each location were then combined to generate a stereopsis map. This stereopsis map was compared to monocular microperimetry measured in a scanning laser ophthalmoscope that mapped out the functional extent of the scotoma in each eye. Across all observers, the parts of the visual field outside the union of the two eyes' scotoma predicted regions with stereopsis, whereas the intersection (overlap) of the scotomata predicted the functional binocular vision field. This explains why individuals with non-overlapping scotomata in the two eyes may have intact binocular visual fields, but be severely compromised in tasks of daily living that benefit from stereopsis, such as eye-hand coordination and navigation.

Acknowledgements: NIH R01EY027390

Poster Session C > Binocular Vision: Stereopsis > Poster C103

A Revolutionary Method of Infant Acuity Measurement

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We have discovered that the preferential detection of motion by an infant combined with the stationary strobic photoreceptor stimulus of a spinning segmented ring (using resolution acuity rather than recognition acuity) can be used as a precise and efficient methodology for measuring infant acuity. The spinning segmented ring can be either black segments with equally sized white gaps or other paired color combinations such as red/gray, green/gray, blue/gray, blue/black, or green/white among other permutations. When a dual configuration of identical segmented rings is presented, with only ONE of the rings as spinning, the smallest segmented ring (either left or right and regardless of the direction of spin) detected as spinning is the acuity endpoint. Previous acuity tests using the strobic stimulus of a stationary segmented ring (primary black/white segments on a gray background) have demonstrated a high degree of precision (6x) and efficiency (4x) versus static-letter tests, but preliminary tests with infants demonstrated that the dual black/white-on-gray format was too sophisticated for infant (primitive) visual systems. That format was simplified to have only ONE spinning ring with black (and white) segments on a white background at either the left or right periphery of the computer screen. The simpler format discovered that the infant would preferentially look at the spinning ring regardless of which side of the screen it was located, and continue to track the left or right location of the spinning ring until the stimulus of the white gaps between the black segments became smaller than the Minimum Area of Resolution.

Visual Search: Attention, individual differences

Transfer of Attentional Sharpening Across Contexts is Stimulus-Specific

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When targets frequently co-occur with highly similar distractors, attentional sharpening is observed wherein target feature representations are narrowed to aid target-distractor discriminations. This sharpening might be due to local tuning mechanisms through increased activation of target values along with suppression of learned distractor values (i.e., sharpening limited to learned features). Conversely, adjustments in global control settings may aid in conflict resolution more generally (i.e., sharpening is transferable to unlearned features). To contrast these models, we asked participants to locate and respond to color targets that co-occurred with two colored distractors (either from an intermediate distance +/-60º or near distance +/-30º from the target in hue space). Additionally, participants were assigned to either Mostly Intermediate or Mostly Near groups where the proportion of intermediate displays to near displays was 80:20 or 20:80, respectively, during a training phase. Following training, the ratio of intermediate to near displays was set to 50:50. In this transfer phase, the target and distractor colors either remained the same (Experiment 1) or changed (Experiment 2). In line with attentional sharpening, during the training phase distractors near the target color in hue space were less interfering for the Mostly Near group than for the Mostly Intermediate group. Critically, this attentional sharpening persisted in the transfer phase only when the target color remained constant. Thus, because the transfer of attentional sharpening was limited to trained features, our results indicate that this process occurs through local tuning processes rather than through broader attentional control mechanisms.

Increasing target template precision decreases distractor recognition in hybrid search

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Suppose you were at the grocery store with a memorized list of products to look for. After finding all of your groceries, would you remember any of the products you saw that were not on the list? Could the length of your grocery list and the similarity of the items on it determine the quality of your memory for those products you did not purchase and were not looking for? Prior research shows that distractors in visual search can be incidentally encoded into memory and that increasing the search difficulty leads to better retention. To examine the effect of template precision on distractor memory, we employed a hybrid search paradigm in which the number of and similarity of target images within the

memory set were manipulated between blocks. Participants memorized sets of 2 or 16 images with all images in a set being either in the same category (high uniformity condition) or all from different categories (low uniformity). They then searched for targets from the memory set within a visual array among distractors. All distractors were sampled from different categories and appeared roughly 30 times throughout the experiment. Finally, participants completed a surprise memory test on their recognition for distractor images. Each distractor appeared alongside a novel foil image that was sampled from the same category as the distractor but had never been previously displayed. We found that memory sets with a higher number of images had higher levels of distractor recognition and that memory sets with lower uniformity had higher distractor recognition. These factors interacted such that recognition of distractors was higher for memory sets with both lower uniformity and more images. Our results suggest that target template precision can account for some changes in distractor memory.

Acknowledgements: This work was partially supported by the Binational Science Foundation (Grant #2018106 to T.D. and R.L.)

Poster Session C > Visual Search: Attention, individual differences > Poster C123

Generalization of attentional control strategies across distinct tasks

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When navigating in a grocery store, how do you quickly find an item on the shelves? Depending on your strategy choice, you can selectively search for items with a particular feature like color or shape, focus your attention to spatial locations where you predict the item might be, or just serially search through everything until you find the target. Recent research has shown that individuals vary substantially in strategies like these when approaching visual search tasks, but such strategies have not been shown to generalize across different visual search tasks (Clarke et al., 2020). We have hypothesized that strategy may generalize to some degree, specifically across tasks that make use of similar attentional components. This has led us to begin systematically probing which task components are necessary for generalization. Our approach is to have participants perform two tasks, in which some task component differs between the two, and measure whether strategy generalizes across the change. Here, we employ the Adaptive Choice Visual Search (ACVS; Irons & Leber, 2018), a paradigm explicitly designed to measure attentional control strategy. In two experiments, we had participants complete the standard ACVS and a modified task with one altered attentional component (specifically, the requirement to use feature-based attention and enumeration, respectively). The results showed positive correlations in strategy optimality between tasks that do or do not involve feature-based attention ($r = .38$, $p = .0068$) and across tasks that do or do not require enumeration ($r = .33$, $p = .018$). The results show that strategy can generalize across at least some changes in attentional task requirements. Future studies will continue to vary additional task components to determine the critical boundaries in which strategy generalization breaks down.

Acknowledgements: This work was supported by BCS-1632296 and BCS-2021038 to A.B.L.

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Quantifying distraction in a visual search task

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Variants of the visual search task have been used to provide key insights into how individuals search for relevant information amongst irrelevant content. Using this task, researchers have sought to answer questions about when attention is necessary for search, the role of inhibition of return during search, and whether social information is “more distracting” than other types of content. In spite of this widespread use, consideration of the semantic meaning of one’s chosen distractors has not been taken into account. Thus here we sought to quantify distraction at the level of semantic similarity, rather than the more common technique of controlling for low-level luminance information. We quantified semantic similarity through the use of word vectors. To do so, we employed vector models, which represent words as lists of numbers created by machine learning models trained on large collections of text. The more semantically and syntactically similar two words are, the closer their word vectors, allowing us to measure word similarity. We chose 5 target categories with 2 targets each, and then created 10 levels of varying similarity between the target and a main distractor. On each trial, participants were told which target item to search for amongst a display of 6 images, and were

instructed to click on the image with a cursor as soon as they found the target. For half of the trials, the target and main distractor images were beside each other, and for the other half of trials they were across from each other. Accuracy declined as semantic similarity increased, and participants were faster to find the target when the main distractor was located beside as compared to across from the target. Together, our data suggest that the location and similarity between a target and distractor have an effect on attention.

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Transitions in daylight saving time negatively affect visual search performance

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Visual search—looking for targets among distractors—underlies many critical professions (e.g., aviation security, radiology, various military operations) and often must be performed optimally regardless of the time of day, week, month, or year. However, external events can potentially disrupt the ability to perform, making it important to understand any systematic influences. The current study examined one such specific influence that can possibly affect an entire workforce at the same time: Daylight Saving Time (DST) transitions—when the clock shifts forward or backward by one hour. Performance on a complex visual search task was assessed using “big data” from the mobile gaming app Airport Scanner (Kedlin Co.), wherein players take on the role of airport security officers searching simulated bags for targets. Performance was compared between individuals who played one specific level during the seven days leading up to a DST transition (pre-DST) and those who played the same level during the seven days following a transition (post-DST). Pre-registered comparisons (https://aspredicted.org/blind.php?x=zs9i5d) revealed that, relative to the pre-DST group, the post-DST group was significantly slower, had more false alarms, was less likely to complete the level, and was more likely to fail due to running out of time. Gameplay on a control set of data (where performance was assessed between individuals who played the level before or after a Sunday without a DST transition), revealed no significant differences in performance. These results suggest that even minor, one-hour time shifts can create problems as they can adversely affect cognitive functioning; when an entire workforce undergoes a sudden time shift in unison (e.g., DST transition), the problems can be exacerbated for the broader system. The current study lends support to many existing efforts to end the archaic practice of DST.

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Visual search dynamics in amblyopic adults

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Amblyopia is a developmental disorder of spatial vision. In addition to basic low-level visual deficits, there is evidence suggesting that amblyopes also have some cognitive deficits, namely in perceptual decision-making and visual search, both of which rely on gathering sufficient evidence to process a visual stimulus. A prior study found that latencies were significantly longer in complex visual search tasks in the amblyopes with either eye viewing, when compared to visually-typical participants. The goal of the current study was to examine the effects of amblyopia on the dynamics of visual search to understand what aspects of visual processing are affected. We used a speed-accuracy trade-off (SAT) procedure to examine these dynamics. We tested both visually-typical and amblyopic adults monocularly on a 4 x 4 visual search display, presented for various durations ranging from 40ms to 2000ms. In the search array, one letter “L” was the target and many letters “T” were distractors. The target letter could appear in any location within the array and the remaining locations were populated with heterogeneously oriented T’s. The participants were tasked to find the target “L” and report its direction (left- or right-facing) within a 365ms response window. Eye movements were tracked and recorded. We found that amblyopes’ latencies were significantly slower for the non-dominant eye than for the fellow eye, which was similar to each eye of visual-typical participants. Amblyopes also showed impaired accuracy with the amblyopic eye viewing. Their SAT function’s asymptote (corresponding to discriminability) and the pre-asymptotic rise

(corresponding to the rate of information accrual) were both lower for the amblyopic eye only. This result shows that amblyopia is not only marked by impaired discriminability and longer response latency, but it is also characterized by a slower rate of information accrual during amblyopic eye viewing.

Poster Session C > Visual Search: Attention, individual differences > Poster C127

You are the type of searcher you are instructed to be: The impact of task instructions on search in the absence of feedback

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Professions such as radiology and aviation security rely on visual search—the act of looking for targets among distractors. Often the searchers must perform in the absence of immediate feedback, which can create situations where performance may be disproportionately driven by the searchers' expectations. For example, if searchers do not expect difficult targets, they may find easy-to-spot targets but systematically quit searching before finding more difficult ones. Without feedback, as is often the case in real-world search, searchers may reinforce their initial expectations (e.g., falsely believing difficult targets are rare) and create self-fulfilling biases (e.g., I need only search for easy targets). Here, two groups of participants completed an identical multiple-target visual search task which differed only in the initial instructions. Those in the "high-expectation" condition were told that each trial would have 1 or 2 targets present (i.e., suggesting no target-absent trials) and those in the "low-expectation" condition were told that each trial would have up to 2 targets (i.e., suggesting there could be target-absent trials). The low-expectation group had a lower hit rate and quit trials more quickly, consistent with a shift in quitting threshold. This effect was present from the start and remained stable across blocks. In sum, the current results suggest initial expectations can have long-term consequences, such that searchers who do not expect to find a target become less likely to find a target.

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Selective attention bias between the eyes in adults with amblyopia

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Our previous study reported that attentional modulation in the visual cortex from input of the amblyopic eye is substantially reduced in adults with strabismic amblyopia, suggesting that interocular attention asymmetry (bias) may play a role in amblyopic suppression (Hou et al., 2016). In this study, we measured selective attention allocation from each eye of adults with anisometropic and strabismic amblyopia by using dichoptic attention stimuli that induce interocular suppression. Specifically, the dichoptic stimuli consisted of highly visible targets (i.e., vertical Gabors with 2 cpd spatial frequency at ≥ 25% contrast) displayed in the tested eye, while distractors (i.e., horizontal Gabors) were simultaneously displayed in the non-tested eye. A 500 ms-valid attentive cue preceded each trial indicating which eye would get the targets. The task was to quickly search for and count the targets among distractors through a mirror stereoscope. The targets were arranged at 50% probability in each eye in a random order within a block. Interocular contrast difference was neutralized by increasing contrast to the stimuli of the amblyopic eye to allow equal-perceptual visibilities between the eyes. Our results showed that the searching and counting performances in the amblyopic eye of individuals with anisometropic and strabismic amblyopia were significantly worse compared to those in their non-amblyopic fellow eye and normal vision eyes, suggesting selective attention deficits in the amblyopic eye under experimental environment of interocular suppression. The performances in the fellow eye of strabismic individuals were also worse compared to those in the eyes of normal-vision controls. Interocular attention bias was computed as the difference in performance between dom/fellow and non-dom/amblyopic eye conditions. Our data revealed that there was no attention bias between the eyes in normal vision; however, selective visual attention was biased toward the fellow eye in both types of amblyopia.

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Poster Session C > Visual Search: Attention, individual differences > Poster C129

Bilingual Non-Selective Activation Modulates Attention During Visual Object Search

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Bilinguals concurrently activate representations of word referents within each of their known languages (i.e., non-selective activation). As a result, both first (L1) and second language (L2) communication may be obstructed when words share orthographic form but not meaning (i.e., interlingual homographs). In the case of interlingual homographs, non-selective activation of conflicting representations burdens working memory, as both interpretations remain activated until contextual information resolves ambiguity. The ways in which the bilingual language system manages this has been studied extensively; however, less is known about how it interacts with the visual system in the context of object processing. To investigate how non-selective activation extends to visual object processing, we tested Fifty-eight bilingual participants on a visual object search task that manipulated cross-language ambiguity. Participants first completed this task in their L1 and then their L2. Each block included search targets corresponding to either interlingual homographs or language-unique words. Their task was to decide whether one of the ten images shown in the search array corresponded to a visually presented word cue. When cued with an interlingual homograph word, the search array contained both representations of the word. We further manipulated search difficulty by presenting a semantically related distractor object on some trials. Our results showed that response accuracy was lower and overall reaction times were longer for interlingual homographs compared to language-unique words. Verification times were longest for homograph searches where no semantic distractor was present. This suggests that the additional working memory load introduced by the presence of a semantic distractor does not impact search performance, but may reinforce the target-language context aiding participants' search performance. More broadly, this suggest that bilingual language processing interacts with visual object processing, as participants flexibly adapted their search strategies, integrating information from the visual display to resolve cross-language ambiguity.

Poster Session C > Visual Search: Attention, individual differences > Poster C130

Learning to identify visual signals of intentionality

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The human visual system not only provides information about the physical state of the environment, but it also provides information about the causal structures that underlie it. One example is our ability to perceive animacy and intentionality. Even when viewing displays of simple shapes on computer screens, we tend to interpret certain cues (e.g., self-propulsion) as being strongly indicative of animacy or intentionality. One of the tasks that involve strong cues of animacy and intentionality is predatory chasing behavior. Here we employed an experimental setup that tests participants' ability to detect and identify visual signals of intentionality using a chasing task in a noisy environment. Participants viewed videos where one red dot ("sheep") is trying to escape from one chasing white dot ("wolf") that is hiding among 19 other randomly moving white dots. The participants' task was to detect and identify which of the 20 white dots was the wolf. The videos themselves were generated using data from another group of participants, who actually either played as the sheep against a computer-controlled wolf or played against each other, one human as sheep and one as wolf. The videos were further categorized based on whether the sheep was eventually caught or not. We found that when participants viewed these videos, they were more accurate at detecting the wolf in human vs. computer trials than in human vs. human trials. We also found that participants' detection accuracy varied significantly across trials even within the same condition. For each video we quantified the extent to which the wolf showed "direct chasing" behavior. We found that the more direct chasing behaviors in a trial, the easier it was for participants to identify the wolf. Our results show that participants could identify intentional agents in noisy environments based on certain behaviors utilized by the agents.

Acknowledgements: McPherson Eye Research Institute

Poster Session C > Visual Search: Attention, individual differences > Poster C131

A General Model for Medical Stimuli Synthesis

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Medical image perception research is clearly important, but it is difficult for researchers to use authentic medical images as stimuli in a controlled manner. On the one hand, public medical image datasets are relatively uncommon, often incomplete, and the data processing and labeling required for real images can be prohibitively time-consuming. On the other hand, it is hard to find medical images which have the desired experimental attributes (e.g., lesion types, locations, etc.). Therefore, the stimuli that are used for medical perception experiments are often highly artificial. While these stimuli are easily generated and manipulated, they are routinely critiqued for being obviously unrealistic. Thus, generating authentic looking (i.e., metameric) medical stimuli is important for medical image perception research. Here, we used the Generative Adversarial Network (GAN) to create perceptually authentic medical images. For different image modalities (e.g., MRI, CT, etc), the generator of the GAN was trained to approximate the realistic image manifold, given modality-specific training data. We used a variety of publicly available medical image datasets for training, including DDSM, DeepLesion, and fastMRI. Novel (fake) radiographs were synthesized by sampling from the learned image manifold. Our method was capable of manipulating the stimuli to match desired experimental attributes, such as texture and shape. We generated desired radiographs that included torso, limbs, and chest. Untrained observers and expert radiologists then completed a psychophysical experiment which required them to distinguish the real from fake (generated) radiographs. The resulting ROC analysis revealed consistent but near chance performance, indicating that observers attended to the task but could not reliably distinguish the real radiographs from our generated ones. The method, therefore, provides a means of creating realistic stimuli for medical image perception experiments.

Poster Session C > Visual Search: Attention, individual differences > Poster C132

Missing what is right in front of our eyes

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When we search for something in a scene, it is obvious that we are more likely to find that target in the next moments if it is near fixation. This is true even if items are large and well-separated and is even more evident in any real-world, cluttered scene. This notion of a searchable region of processing around the point of fixation is formalized as the “Useful Field of View” (UFOV) or Functional Visual Field (FVF). We might assume that, if a simple target falls inside the current FVF, it will be found and fixated by the next saccade, but this is not the case. We recorded eye movements as 22 observers searched for Ts in a grid-like display of Ls. For each fixation, we measured the distance to the target and calculated the probability that the next saccade would go to the target. Even when the target was a neighboring item (<2 deg away), that probability was about 45%. Two degrees is well within any estimate of the FVF radius for these stimuli. If the task is made harder, probability drops to 34%. If the criteria are loosened to include any of the next 3 fixations (to allow for corrective saccades, etc), probability only rises to 68%. Similar results were obtained for 18 radiologists reading mammograms. The FVF defines a region where a target CAN be found but the need to selectively attend to individual items means that detectable items may not be detected. At the same time, introspection assures us that we have looked at the fixated region. Hence, we can be surprised when we fail to find targets in places where we believe that we have searched.

Acknowledgements: NIH-NCI grant CA207490

Poster Session C > Visual Search: Attention, individual differences > Poster C133

Guiding search in 3D volumes with 2D synthesized images

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Introduction: Three-dimensional volumetric images have become prevalent for cancer detection tasks by allowing radiologists to segment features of interest from anatomical background noise (e.g., breast parenchyma). However, spatially small 3D targets that are hard to detect in the visual periphery are often not foveated and then missed. Radiologists are routinely presented with a 2D synthesized image (2D-S) of the 3D volumetric images to assist the 3D search. We investigate the visual-cognitive processes by which the 2D-S benefits the 3D search for small and large targets. Methods: Six trained observers participated in a hybrid Yes/No, rating, and localization search task. They searched for either a small (0.15 deg) or large (0.5 deg) target in 3D volumes (100 slices) with or without an additional 2D-S. We applied a high pass filter and a pixel-wise maximum operation across the 3D slices to produce the 2D-S image. Results: The presence of the 2D-S image improved observers' hit rate (ΔHR= 0.31, p<.001) and correct localization rate (ΔCL= 0.278, p<.001) of small targets in the 3D images. For larger targets, there was a smaller improvement (ΔHR= 0.115, p>.05). Eye movement analysis showed significantly fewer search errors in the 2D-S + 3D condition relative to the 3D condition for the small target (M3D+2D-S= .15, M3D= .45, p<.001). The presence of the 2D-S image resulted in a pattern of search consistent with guided drilling behavior: fewer eye movements to foveate the small target (M3D+2D-S = 24.5, M3D = 44.9, p<.05), fewer reversals in scrolls (M3D+2D-S = 7.5, M3D = 14.29, p<.01), and shorter response times (M3D+2D-S = 22.81 sec., M3D = 34.92 sec., p<.01). Conclusion: Our results suggest that 2D synthetic images effectively guide 3D search towards likely target locations, resulting in guided drilling behavior and reduced search errors for small targets difficult to detect in the periphery.

Poster Session C > Visual Search: Attention, individual differences > Poster C134

How does a 2D preview help a 3D search? – An eye tracking study of Digital Breast Tomosynthesis

View Poster | Play Video | Visit me in Gather.Town Egret Room on Sunday 4:00 pm - 6:00 pm EDT

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Digital Breast Tomosynthesis (DBT) is a technology that renders the 3D volume of the breast as a stack of images that a radiologist can scroll through. DBT has been shown to produce higher hit rates and lower false alarm rates than traditional 2D mammogram (breast x-ray). However, it comes with an additional time cost of about 50 – 100% per case. In the current study, we investigated whether providing a 2D preview before reading DBT can help the radiologist read DBT more efficiently. Two versions of a 2D breast x-ray were tested: 1) standard mammogram (MMG), 2) synthetic "C-View" image – a 2D view synthesized from the 3D DBT data. Results were compared to a no-preview control. Radiologists were allowed to view preview as long as they wanted but they could not revisit the preview once they started to read DBT. Radiologists were asked to mark all potential lesions in DBT by mouse click and were asked whether they would recall the patient for further examination. The results show that providing either mammogram or C-view preview decreased the reading time in DBT, but this benefit was completely offset by the time spent on the preview. Providing either MMG or C-View preview reduced the false alarm rates, but C-view preview also reduced hit rates. Eye movements data show that when there was a preview, radiologists tended to fixate on a lesion faster and cover the less of the breast area than in the no preview condition. Radiologists also made smaller saccades to initiate search after seeing the preview. Our results suggest that providing this type of preview may not save time in reading DBT, though it does add different information which can change search strategy and effectively guide attention.

Acknowledgements: NIH-NCI grant CA207490

Poster Session C > Visual Search: Attention, individual differences > Poster C135

Does feature priming guide your whole visual search?

View Poster | Play Video | Visit me in Gather.Town Egret Room on Sunday 4:00 pm - 6:00 pm EDT

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Features from the last thing you looked for influence the next thing you look for. Priming has been proposed as a potent source of guidance of attention (Theeuwes, 2013). There is no doubt that attention to, for example, red on one trial, speeds search for red on the next. There are, at least, three ways this might happen. Priming might speed the motor response once the target is located, guide the first deployment of attention, or prioritize all red items in the next search. To test the hypothesis that priming guides the entire subsequent search, observers searched for a red or green letter T, present on every trial, in arrays of red or green Ls. In the localization version of the task, observers clicked on the T. In the 2AFC version, they identified the T as red or green. Color was irrelevant and not predictive. If priming by color persists across the entire search, attention would be biased to all items of the primed color and the slope of the RT x Set Size function would be shallower when the target color remained the same. There was no such reduction in slope. In the localization condition, RTs were faster when colors repeated than when they did not (40 msec diff, $t(15) = 5.36$, $p < 0.01$). In the 2AFC condition, this result was replicated (30 msec diff, $t(15) = 2.52$ $p = 0.02$). There was no significant effect on slopes in either condition ($p > 0.40$). These results suggest that priming could influence either the first deployment of attention or the speed of motor response, but they also suggest that sustained color feature priming does not last throughout search. Kristjansson, Wang, & Nakayama (2002) found similar results with a somewhat different task.

Poster Session C > Visual Search: Attention, individual differences > Poster C136

How Do Expectations of the Upcoming Search Difficulty Alter Search Performance?

View Poster | Play Video | Visit me in Gather.Town Egret Room on Sunday 4:00 pm - 6:00 pm EDT

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Real-world search difficulty is highly variable, but can be reliably anticipated sometimes (e.g. finding your car in an empty parking lot). During a difficult block of trials, performance decreases, but observers who hold more target detail in visual-working memory mitigate the performance decrement associated with difficult search (Schmidt, & Zelinsky, 2017). Given this, expected search difficulty may significantly drive performance. This study examined expected difficulty effects in simple stimuli (Landolt-C’s; Experiment 1) and real-world objects (RWO; Experiment 2). We recorded eye-movements as participants performed blocks of easy, moderate, or difficult search created by manipulating the number of target similar distractors. Observers localized previously cued targets within a semi-circular array of six items. Expectancy was assessed by examining the change in search performance between trials that matched the block difficulty level (Experiment 1: 83.33% & Experiment 2: 75.00% of trials), and trials that were easier or harder than expected. In both studies, increased search difficulty resulted in reduced accuracy, increased RT, and increased time spent fixating targets and distractors (all $p<.05$). Search guidance was at chance in Experiment 1 ($p=.422$), and above chance in Experiment 2, but decreased with increasing search difficulty ($p<.001$). Searching for simple stimuli and expecting an easy search, but performing a more difficult search, resulted in reduced accuracy, less time fixating targets and fixating distractors (all $p<.01$). Expecting a difficult search, but performing an easier search, resulted in more time fixating targets/distractors and increased RT (all $p<.05$). RWO’s replicated the easier than expected effects in RT and time spent fixating distractors, and additionally observed a decrease in target guidance (all $p<.05$). Overall, expectancy changes performance to make it more like the expected search difficulty. Consequently, these expectations should only change performance by some fractional difference between expected and actual difficulty.

Poster Session D

Face Perception 1

Poster Session D > Face Perception 1 > Poster D1

Differential Patterns of Activation and Deactivation among Brain Regions Selective for Face and Scene Processing

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Sunday 8:00 pm - 10:00 pm EDT

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During the past decades, a set of brain regions have been identified as the core system for face processing, comprising occipital face area (OFA), fusiform face area (FFA), and posterior region of superior temporal sulcus (pSTS). Analogously, a set of brain regions have been identified as the core system for scene processing, including occipital place area (OPA) (or transverse occipital sulcus, TOS), retrosplenial complex (RSC), and parahippocampal area (PPA). Here we investigated how activities of selective brain regions may be modulated (activated or deactivated) by their preferred versus non-preferred category of stimuli. Twenty-five participants were asked to perform a one-back working memory (WM) task while viewing sequences of face and scene stimuli, with brain images being scanned using the fMRI. In addition, a sequence of object images was used as baseline control. The results showed that positive activations were found for brain regions selective for face processing in contrast to object control, whereas those selective for scene processing exhibited deactivation in contrast to object control, when participants performed the 1-back WM task on faces. In contrast, brain regions selective for scene processing exhibited a pattern of positive activation and those selective for face processing exhibited a pattern of deactivation, when participants performed the 1-back WM task on scenes. These differential patterns of activation and deactivation among brain regions exhibiting category selectivity for face and scene processing are consistent with findings from the previous research. Furthermore, they also collaborate with our recent findings, showing that orienting attention to either the face or scene aspect in processing face-scene compound stimuli may help generate activations in addition to those evoked by images of specific categories. In other words, the additional activation elicited as a result of attentional allocation may be able to counter the deactivation caused by the non-preferred aspect of the compound image.

Acknowledgements: Ministry of Science and Technology, Taiwan, R.O.C.

Poster Session D > Face Perception 1 > Poster D2

Modulating Activation of Brain Regions Selective for Face and Scene Processing: The Effects of Attentional Orienting

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Sunday 8:00 pm - 10:00 pm EDT

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Ever since the identification of brain regions selective for face processing, there has been a myriad of studies demonstrating face selectivity of such regions. Likewise, brain regions selective for scene processing also have been identified in recent years. However, there have been relatively few studies investing how the two networks interact and integrate in processing faces viewed against scenes, which represents a modal depiction of our life experiences. Here we examined how activation of brain regions selective for face and scene processing may be modulated by orienting to different aspects of face-scene compound images. Specifically, participants were asked to make personality judgment regarding the face or category judgment regarding the background scene, while brain images were undertaken with the fMRI. In addition to compound images, face-only and scene-only images were used as controls. Prior to the orienting

task, participants undertook the 1-back WM task to localize brain regions selective for face processing (i.e., FFA) and scene processing (i.e., PPA). The regions of interest identified via the localizer task were then used to examine the effect of orienting on brain activation. The results showed that, for FFA, brain activation was strongest with face-only images, followed by face-scene compound images when participants oriented their attention to the face and weakest for scene-only images. In contrast, for PPA, the strongest activation was found with scene-only images, followed by compound images when participants oriented their attention to scenes, and weakest for face-only images. These results collaborate with previous studies with respect to activation for brain regions selective for face and scene processing. Furthermore, they suggest that when viewing images depicting a face against a scene, our processing of such images and perhaps the memory of them may well depend on our momentary attentional allocation to either the face or scene aspect of such images.

Acknowledgements: Ministry of Science and Technology, Taiwan, R.O.C.

Poster Session D > Face Perception 1 > Poster D3

Brain activity reflecting social values associated with faces during binocular rivalry

View Poster | Visit me in Gather.Town Osprey Room on Sunday 8:00 pm - 10:00 pm EDT

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We learn meaningful information about other individuals through repeated social interactions. However, the influence of the acquired social information on visual perception and the potential interactions between the neural mechanisms of social associative learning and social perception are understudied. Here, we used binocular rivalry (BR) and fMRI to investigate the neural correlates of social associative learning and its impact on perceptual selection. The experiment consisted of three stages: pre-learning BR, Trust Game (TG), and post-learning BR. After performing pre-learning BR outside the MR scanner, the brain activity of the participants was monitored during the latter two stages. During BR, eight face-scene image pairs were presented dichoptically while participants were tracking their dominant perception. During TG, participants played an investment game with several faces presented during BR. Each face was repeatedly presented and was assigned to one of three conditions (generous, intermediate, selfish) based on the portion of payback. Results from TG showed greater BOLD activity in the ventromedial prefrontal cortex (vmPFC) for “generous” faces after learning has occurred, compared to before learning or for other face conditions. In post-learning BR, “generous” faces tended to be perceptually dominant longer compared to pre-learning BR. Also, “better learners” (i.e., participants who made differential investment based on the faces’ generosity during TG) showed greater activation in the face-selective areas including the left fusiform face area and the left amygdala when “selfish” faces were dominant. Functional connectivity analysis revealed that vmPFC showed greater connectivity with two subregions of the anterior cingulate cortex when “generous” faces were dominant. Taken together, the current results show brain activation reflecting social values of faces acquired through associative learning and activation in face-relevant regions modulated by the learned social value, which implies potential linkage between social associative learning and social perception.

Acknowledgements: Supported by NRF-2017M3C7A1029659

Poster Session D > Face Perception 1 > Poster D4

Individual differences in susceptibility to temporal contextual cues during classification of facial expressions

View Poster | Visit me in Gather.Town Osprey Room on Sunday 8:00 pm - 10:00 pm EDT

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Temporal cues such as affective vocal tones and scenes are well-known to alter people’s perceived category of facial expressions. However, it is unclear whether there are individual differences within typical adults in their susceptibility to temporal cues when classifying facial expressions. To examine this, we asked twenty-four participants, aged between 18 and 25 years, to classify a series of dynamic facial expressions that gradually unfolded from neutral to happy or sarcastic smiles. In two experimental conditions, facial expressions were temporally preceded by affective contexts:

audiovisual clips depicting a happy or an angry scenario. The preceding contexts in a third condition ("no-context") had no affective information (i.e., visual and auditory noise). First, compared to classifications in the no-context condition, classifications were more accurate ($p < 0.001$) when the affective contexts predicted the impending facial expressions (i.e., happy clips paired with happy smiles and angry clips paired with sarcastic smiles), suggesting facilitation from predictive contexts. A Pearson's test of correlation revealed that, the less accurate our participants were at classifying facial expressions with no affective context, the higher the magnitude of this facilitation (i.e., increase in accuracy) was ($p < 0.001$). Second, compared to the no-context condition, classifications were relatively less accurate ($p = 0.010$) when the affective contexts were misleading (i.e., happy and angry clips paired with sarcastic and happy smiles, respectively), suggesting impairment from misleading contexts. There was no significant correlation between our participants' accuracy to classify facial expressions without an affective context and the magnitude of these impairments (i.e., decrease in accuracy). Our findings suggest that people who are poorer at classifying facial expressions appearing without contextual information may be relatively more influenced by predictive, but not misleading, temporal cues when contextual information is available. Therefore, individual differences seem to modulate susceptibility to contextual cues when classifying facial expressions.

Poster Session D > Face Perception 1 > Poster D5

The Subjective Duration of Looming and Receding Emotional Faces

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Sunday 8:00 pm - 10:00 pm EDT

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Time perception is not veridical, but, rather, it is susceptible to environmental context, like the intrinsic dynamics of moving stimuli. The direction of motion has been reported to affect time perception such that the movement of objects toward an observer is perceived as longer in duration than that of objects away from the observer. This looming-motion-induced time dilation has been explained in terms of an arousal-based or an attentional mechanism (or a combination of both). The current study was interested in which of these two explanations represents a more viable mechanism. With this aim, we investigated how the looming/receding temporal asymmetry is modulated by the emotional contents of stimuli. In two experiments, participants were shown face images expressing three emotions (angry, happy, and neutral) for one of seven target durations (400-1000ms) and performed a temporal bisection task by judging each presentation duration as "short" or "long". In Experiment 1, the face images were shown in a constant-sized, stationary position. In Experiment 2, the images were expanding (looming) or contracting (receding) in size. In Experiment 1, we found no influence of facial emotion in perceived duration. In Experiment 2, however, looming stimuli were perceived as longer in duration than receding ones, replicating previous findings of the looming-induced time dilation using naturalistic human-face stimuli. More importantly, in Experiment 2 we found an interaction effect between arousal rating of faces and motion direction: The looming/receding asymmetry was pronounced when the arousal of the presented images was rated low, but this asymmetry diminished when arousal was high. These results suggest that (1) affective characteristics of looming stimuli can modulate temporal processing and more specifically, (2) the looming/receding asymmetry is reduced when arousing facial expressions enhance attentional engagement to receding stimuli, supporting the attentional mechanism of the looming-induced time dilation.

Poster Session D > Face Perception 1 > Poster D6

Pattern completion of object-level information in classification images of Mooney faces

View Poster | Visit me in Gather.Town Osprey Room on Sunday 8:00 pm - 10:00 pm EDT

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Humans are highly sensitive to incomplete and partial visual information, resulting in object and scene recognition that proceeds seemingly unimpaired by occlusions and noise. Many examples of this have been reported, including contour and surface-based filling-in and patten completion. However, less is known about whether and how pattern completion for high-level object and face representations occurs. Here, we tested for pattern completion of holistic object representations by measuring classification images of Mooney faces. Mooney faces are two-tone black and white blobs that are readily perceived as faces despite lacking low-level face features. In our experiment, participants viewed two identical Mooney face images embedded in random but complementary noise and they selected which was more female-like. Classification images were computed by averaging the selected noise images, and null distributions were generated from shuffled responses. We operationalized pattern completion as the information present in the classification image only within the black regions of the Mooney face. These black regions do not contain any signal, so any consistency in the selected noise images within these areas would suggest that the observer has perceptually completed parts of the face that were not originally there. We found significant within-subject correlations within these black regions, indicating that there is pattern completion in high-level object representations. The results cannot be explained by known contour integration, surface filling-in, or feature-based pattern completion processes. It does, however, corroborate the commonly held assumption that Mooney face recognition is supported by matching the impoverished images to stored templates.

Poster Session D > Face Perception 1 > Poster D7

The Effect of Image Variability on Matching Unfamiliar Own and Other-Race Faces

View Poster | Visit me in Gather.Town Osprey Room on Sunday 8:00 pm - 10:00 pm EDT

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Matching the identity of unfamiliar faces is highly error-prone, especially when the face is a different race to the viewer. This is referred to as the other-race effect (ORE). Recent research has tested methods for improving unfamiliar face matching performance and found that exposure to within-person variability (the way a face varies across multiple encounters) improves the identification of unfamiliar own-race faces. The current study investigates whether exposure to within-person variability can improve the identification of other-race faces as well as reduce the ORE. Using a cross-over design (N= 105), Caucasian-Australian and Asian-Singaporean participants completed a simultaneous matching task with Caucasian and Asian faces. Participants viewed a target image with either one other ambient image or an array of three ambient images and judged whether the identity in the array was the same or different to the target image identity. Results showed that viewing multiple images improved matching accuracy for own- and other-race faces in trials where the target image identity was the same as the image array. However, multiple images decreased accuracy in trials where the target image was a different identity. Notably, although multiple images improved accuracy for matching other-race faces, the improvement was not different from that for own-race faces. That is, the ORE was not reduced. This pattern was also shown in the analysis of signal detection measures. These findings highlight the robust nature of the ORE and provide insight into the formation of familiar face representations.

Poster Session D > Face Perception 1 > Poster D8

Racial ambiguity impairs holistic face processing

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Sunday 8:00 pm - 10:00 pm EDT

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Face experience has been regarded as a crucial factor that drives the formation of holistic face processing, a hallmark of perceptual expertise. While early work supported this hypothesis by showing stronger holistic face processing in own-race faces than that in other-race faces, more recent studies failed to replicate this observation. This discrepancy challenges the nature of holistic processing: Is it really shaped by experience? To address this question, we examined holistic face processing with novel racially ambiguous faces, created by morphing Asian and Caucasian faces. We also examined holistic processing with unambiguous Asian and Caucasian faces. In each trial, Asian adult participants (N = 28), who had limited experience with Caucasian people, first saw a face image, which is followed by a composite face. They need to decide whether the top half of the composite face was the same person as the first face. The results showed a significant composite effect (misaligned – aligned) for Asian and Caucasian faces, but not for the Asian-Caucasian morphed faces. We replicated this finding in Experiment 2, which also included eye movement measures (N = 36). These findings suggest that the racially ambiguous faces impair holistic processing, which is consistently found in unambiguous faces. To examine whether this finding was caused by the lack of experience with the ambiguous faces, we introduced a brief exposure of morphed faces in Experiment 3 (N = 40). The brief exposure led to significant holistic

processing of morphed faces, as compared to a non-exposure condition. In sum, we reported a robust impairment of holistic processing by racially ambiguous faces. Moreover, we reinstated holistic processing with a brief perceptual experience of this novel type of face. These findings support the crucial role of perceptual experience in the formation of holistic face processing.

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Poster Session D > Face Perception 1 > Poster D9

Upper visual field bias for face detection in infants

View Poster | Visit me in Gather.Town Osprey Room on Sunday 8:00 pm - 10:00 pm EDT

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Upper visual field enables faster face detection compared to lower visual field (Fecteau et al., 2000). This finding suggests a bias that visual attention tends to be directed to a face located in the upper field rapidly, and enhances face processing in the upper visual field. In previous studies, this bias of face processing in the upper visual field has been reported in adults. However, it has been little known about this bias in infants. In the present study, we examined whether infants have the upper visual field bias to the face as seen in adults. In the Experiment 1, we measured eye movements in 7- to 8-month-old infants under two conditions. One was that two female faces were presented either in the upper and lower fields, or in the right and left fields against the central fixation. The infants viewed the two faces for one sec. We calculated the proportion of the first look to each visual field. The results indicated that the proportion of first look to the face in the upper field was significantly greater than that in the lower field, while there was no significant difference between the right and left fields. In Experiment 2, we investigated whether this upper field bias observed in Experiment 1 was specific to faces by replacing the face images with those of houses. Another twenty 7- to 8-month-old infants participated. We found no significant difference between the upper and lower visual fields. Neither between the left and right. These results suggest that the upper filed bias is specific to faces. We argue that 7- to 8- month-old infants might have learned a probabilistic consistency that faces occur frequently in the upper visual field through experience contributing to a processing advantage for faces appeared in the upper visual field.

Poster Session D > Face Perception 1 > Poster D10

The effects of gaze and head orientation on the speed of face categorization during RSVP

View Poster | Visit me in Gather.Town Osprey Room on Sunday 8:00 pm - 10:00 pm EDT

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Humans are fast and accurate in categorizing faces among other objects in natural scenes. While the configurations among face exemplars are highly similar, faces may appear rather differently due to visual variations, such as changes in head orientation and eye gaze. We wonder whether there is a cost to generalize across these visual differences for accomplishing face categorization. The effects of head orientation and perceived gaze direction on face categorization were investigated using a rapid serial visual presentation (RSVP) approach. Observers (N=19) were presented with 15,491 unsegmented natural images (350 faces, 15,141 non-face objects) randomly in rapid succession (SOA=91.7 ms), and were instructed to respond immediately to every face. Faces differed in gaze and head orientation in 7 combinations (50 faces/combination; presented randomly throughout the sequence): Full-front views with (1) direct gaze, (2) left-averted gaze, or (3) right-averted gaze; Left ¾ side views with (4) direct gaze, or (5) averted gaze; and Right ¾ side views with (6) direct gaze, or (7) averted gaze. We found highly accurate responses to faces (95% correct). Crucially, both perceived gaze direction and head orientation had comparable, significant, and non-interactive effects on response time (RT), where responses to direct gaze were faster than to averted gaze by 48 ms, and responses to full-front view faster than to ¾ side view also by 48 ms. Full-front faces with direct gaze (RT=454 ms) led to an additive speed advantage (96 ms) to ¾ faces with averted gaze (RT=550 ms). We found no significant RT differences between left and right gaze aversions, or between left and right ¾ side views. The results suggest that the effects of perceived gaze direction and head orientation on the speed of face categorization depend on the degree of social relevance of the

face to the viewer.

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Poster Session D > Face Perception 1 > Poster D11

The relationship between facial ensemble representations

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Perceiving and evaluating the overall mood of a crowd is important for social interaction. To evaluate the mood of a crowd, the visual system should consider the average of both the facial expressions and gaze directions of a crowd, because the judgment of facial expression is influenced by its gaze direction (Adams & Kleck, 2003). Previous studies have shown that people can average facial expressions (Haberman et al., 2009) and gaze directions (Sweeny & Whitney, 2014), but they did not show the relationship between them. The current study investigated whether the ability to compute the average of facial expressions was related to that to compute the average of gaze directions. We presented four faces with different facial expressions and gaze directions. Participants ($N = 125$) were asked to estimate the average of facial expressions, that of gaze directions, or both of them sequentially. We calculated the error of each task by calculating the difference between the presented and reported averages and normalizing it by the possible reporting range of each feature. We found that the error autocorrelations of facial expressions and gaze directions were high ($.63 < rs < .94$), indicating that participants were able to compute summary statistics reliably. More importantly, participants' abilities to average facial expressions were correlated with those to average gaze directions ($.37 < rs < .51$). Thus, when facial features are related to each other in the processing of a single face, the ensemble processing of those facial features is related to each other. These results suggest that no relationship between the ensemble processing of facial features found in previous studies (Haberman et al., 2015; Sama et al., 2019) is likely because the facial features examined in the previous studies were not related in the processing of a single face.

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Poster Session D > Face Perception 1 > Poster D12

Direct gaze detection advantage is independent from normal face/eyes configuration

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Sunday 8:00 pm - 10:00 pm EDT

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Direct gaze is a powerful social cue used to indicate the attention of another on oneself and is of such importance to typical everyday social interaction that it is preferentially attended from birth (Farroni et al., 2002). The “the-stare-in-the-crowd” effect showed that searching for faces with direct- gaze eyes is more accurate and faster than a face with averted eyes when direct and averted gaze faces were presented together (von Grünau and Anston, 1995). However, people have a feeling of “being stared” even when others has a mouth-muffle on, suggesting the effect might be independent from a whole face context. In this present study, participants were asked to detect direct/averted-gaze eyes, with or without a target, from four faces. The four faces were in one of such three conditions: normal faces, first-order vertical configuration impaired faces (the eyes area configuration was intact), and scrambled face (eyes were apart). Data showed that “the-stare-in-the-crowd” effect was always there when face first-order configuration or even eyes configuration was impaired. The direct gaze advantage in detection is invariant, independent from face spatial configuration, suggesting gaze processing initiate eyes perception, face perception, and human social interaction.

Acknowledgements: This research was supported by grants from the Zhejiang Provincial Natural Science Foundation of China (LY20C090010, LY19C090006).

Poster Session D > Face Perception 1 > Poster D13

Follow Because of Trust: Trust Modulates the Gaze Cueing Effect

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Sunday 8:00 pm - 10:00 pm EDT

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Faces are extremely important stimuli in social life. People obtain diverse information from someone's facial appearance, such as age, gender, emotions, etc. Evidence shows that people spontaneously form stable trustworthiness impressions from facial appearance rapidly, just like making a quick sketch. However, the functional significance of such mechanisms remains unclear. Therefore, the present study addressed this issue by examining whether extraction of trust information from faces modulates attentional orienting (the flexible hypothesis) or not (the reflexive hypothesis). In this study, participants performed a Posner's cue-target task, in which we used faces that were rated for trustworthiness by another group beforehand as stimuli (more-trustworthy vs. less-trustworthy). Results showed that the gaze cueing effect occurred in the more-trustworthy condition but not in the less-trustworthy condition (Experiment 1), which demonstrated that trustworthiness of facial appearance can modulate the gaze cueing effect. Moreover, the aforementioned trust modulation effect was not due to some low-level characteristics of the face stimuli (Experiment 2). Taken together, these results showed that trustworthiness of facial appearance modulates attentional orienting in gaze following. Our findings imply that the functional significance of the quick sketch with regard to trustworthiness may lie in attentional orienting, thus supporting the flexible hypothesis.

Poster Session D > Face Perception 1 > Poster D14

Vitality makes dynamic faces more attractive than static faces

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In recent years, short-form videos have been exploding on social media. People are addicted to taking vibrant, dynamic selfie videos instead of static selfies. We hypothesized that it is the vividness in videos, compared with static pictures, making people more appealing. Therefore, the present research aimed to investigate whether vitality made dynamic faces more attractive than static ones. We obtained face stimuli from social networks and generated them into three different motion state faces (dynamic, static, and dynamic faces played in scrambled frames). Participants rated the attractiveness (Experiment 1&2), vitality (Experiment 1&2), and subjective processing fluency (Experiment 2) of these faces and were primed with different labels of vitality (high, low, and non) in Experiment 2. As expected, dynamic faces had greater vitality and higher attractiveness than static ones. High-vitality labels made faces more attractive than low-vitality labels. Furthermore, vitality rather than subjective processing fluency mediated the relationship between motion states and facial attractiveness. In Experiment 3, we further examined whether the vitality effect could be generalized to other stimuli. We adopted videos of humans, plants, animals, and inanimate objects as stimuli and generated them into two motion states (dynamic and static). Again, we found vitality mediated the relationship between motion states and facial attractiveness regardless of stimuli type. These results indicate that vitality is an essential factor that accounts for the more attractiveness of dynamic stimuli than static ones.

Acknowledgements: This research was supported by the National Natural Science Foundation of China (32071048).

Multisensory Processing 1

Poster Session D > Multisensory Processing 1 > Poster D15

The effects of stimulus onset and offset asynchrony on audiovisual temporal recalibration

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Sunday 8:00 pm - 10:00 pm EDT

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If visual and audio stimuli are repeatedly presented with a certain constant temporal asynchrony for a few minutes, the perceived temporal asynchrony between the stimuli would be reduced. This phenomenon called as "audio-visual temporal recalibration". Many previous studies have shown that the temporal recalibration could be obtained with short stimuli (up to 20 ms). Therefore, they have not found whether temporal recalibration may occur for both onset and offset

of a long audio-visual stimuli, and whether a constant temporal gap between the onset (or offset) of the audio-visual stimuli would enable the recalibration for the offset (or onset) of the stimuli. The present study focused on these issues. We used a white noise as an audio stimulus and a white circle as a visual stimulus (longer than 200 ms) for which participants easily separated their onset and offset. Experiments consisted of adaptation phase and test phases. In the adaptation phase, the auditory-visual stimuli with a constant temporal asynchrony (-240, 0 or +240 ms) were presented for about 3 minutes. In the test phase, participants judged which of the visual stimulus or auditory stimulus is the first. On the one hand, if participants were exposed to the asynchrony between the onsets of the audio-visual stimuli (or between their offsets) and tested for the temporal order of their onsets (or their offsets), we found stable audio-visual recalibration. On the other hand, if participants were exposed to the asynchrony between the onsets of the stimuli (or between their offsets) and tested for the temporal order of their offsets (or their onsets), we found no substantial audio-visual recalibration. These results suggest that the audio-visual temporal recalibration is restricted to the temporal features of the stimuli which were exposed with a constant temporal asynchrony.

Poster Session D > Multisensory Processing 1 > Poster D16

Audiovisual Spatial Congruency Modulates Perceptual and Metacognitive Components of Sound-induced Flash Illusion

View Poster | Visit me in Gather.Town Osprey Room on Sunday 8:00 pm - 10:00 pm EDT

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Sound-induced flash illusion constitutes a classical phenomenon of audiovisual integration: The fission illusion occurs when two flashes are reported when one flash is paired with two beeps; in contrast, the fusion illusion occurs when one flash is reported when two flashes are paired with a single beep. Here we investigated the spatial modulations on perceptual and introspective experience of the fission and fusion illusions by utilizing the fact that the magnitude of illusions differs in different eccentricity. The visual flashes were presented on a monitor either in the center at which the participants fixate, or in the periphery (10° to the left or right). The participants had to report the number of flashes and rate the confidence regarding the correctness of their report. When the beeps were presented from loudspeakers that is spatially congruent with the flashes, the fission illusion was larger in the periphery than in the center, whereas the fusion illusion was larger in the center than in the periphery. Interestingly, participants also reported higher confidence when either illusion was larger, suggesting that participants considered their illusory experience as genuine. When the beeps were presented from headphones that are spatially incongruent with the flashes, the fission illusion strength was similar in the center and periphery, whereas the fusion illusion remained larger in the center. However, there was no center-periphery difference in confidence rating for both illusions. Hence, when the flashes and beeps were spatially separated, center-periphery difference of the fission illusion was eliminated, and the magnitude and confidence rating of the fusion illusion can be dissociated. Taken together, spatial coincidence is a critical factor for the fission and fusion illusions as manifested in both perceptual and introspective measures. Furthermore, the fission and fusion illusions were sensitive to audiovisual spatial congruency to different extents, plausibly underpinned by different mechanisms.

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Poster Session D > Multisensory Processing 1 > Poster D17

Multi-modal representation of the size of space in the human brain

View Poster | Visit me in Gather.Town Osprey Room on Sunday 8:00 pm - 10:00 pm EDT

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Estimating the size of an indoor space involves examination of visual boundaries that limit the spatial extent of the space and reverberation cues caused by sounds reflected from interior surfaces. Here we used fMRI to examine how the brain processes the geometric size of an indoor scene when various types of sensory cues are presented individually or together. Specifically, we asked whether the size of space is represented in a modality specific way or in a more general,

integrative way that combines multi-modal cues. In a block-design study, images or sounds that depict small and large sized indoor spaces are presented. Visual stimuli consisted of real-world pictures of empty spaces that are small like a closet, or large like a warehouse. Auditory stimuli consisted of sounds recorded in an anechoic chamber convolved with differential reverberation. Using a multi-voxel pattern classifier, we asked whether the two sizes of space can be accurately classified using visual, auditory and visual-auditory combined cues. We discovered that higher-level scene specific regions (OPA, PPA) showed above-chance classification of spatial size when visual cues are presented, but not when auditory cues are presented without any visual information. Conversely, we found that several regions in the transverse temporal gyrus showed above-chance classification for spatial size of scenes for auditory cues, but not for visual cues alone. Interestingly, we found that several areas in the temporal and parietal lobe including the Superior Temporal Gyrus (STG) and the Angular Gyrus (AG) represented spatial size of scenes regardless of the type of sensory cues. Furthermore, these regions also showed high classification accuracy when both visual and auditory cues are concurrently presented. These results suggest that STG and AG may contain multimodal representation of the size of space, and may play a role in integrating multi-sensory cues for spatial size.

Poster Session D > Multisensory Processing 1 > Poster D18

Origins of the Kiki-Bouba effect

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Sunday 8:00 pm - 10:00 pm EDT

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INTRODUCTION. Why do people associate spiky shapes to the word “Kiki” and rounded shapes to the word “Bouba”? One hypothesis suggests that our mouths form angular shapes while saying “Kiki” and rounded shapes while saying “Bouba”. Alternatively, sharp objects produce high-pitched (“Kiki”-like) sounds while rounded objects produce low-pitched (“Bouba”-like) sounds when struck. We investigated these hypotheses using behavioural and computational experiments. METHODS. Ten spiky and ten rounded shapes were created. In Experiments 1 & 2, subjects had to associate each shape to a Kiki-like or Bouba-like word. In Experiment 3 & 4, audio clips were played. Subjects had to associate them with spiky or rounded shapes. The audio clips included pronounceable Kiki-Bouba words; their digitally-reversed counterparts; pure tones with mean frequencies matched to the Kiki-Bouba words and sounds generated when objects were struck. RESULTS. In Experiments 1 & 2, 80% subjects associated spiky and rounded shapes with Kiki-like and Bouba-like words respectively. In Experiments 3 & 4, subjects showed the Kiki-Bouba effect for pronounceable words, reversed words, natural sounds and pure tones. The sound’s mean frequency was positively correlated with the fraction of times it was classified as Kiki-like. To assess whether these associations can be learnt, we took neural networks trained for object recognition (VGG-16) and asked if we could predict the sound spectrum from the object shape on a database containing natural objects and their associated sounds (34 natural objects, 7 materials, falling on 5 surfaces). After training this model, we queried it for the predicted sound spectra for Kiki-like and Bouba-like shapes. The mean frequency of the predicted spectra was strongly correlated with the Kiki-ness of these shapes ($r= 0.8664$, $p = 7.87e-07$). CONCLUSIONS. We conclude that the Kiki-Bouba effect is a consequence of natural associations that can be learnt between objects and their associated sounds.

Poster Session D > Multisensory Processing 1 > Poster D19

The association between audio-visual spatial integration and hallucinations in Schizophrenia

View Poster | Visit me in Gather.Town Osprey Room on Sunday 8:00 pm - 10:00 pm EDT

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It has been suggested that patients with schizophrenia (SZs) show impairment in multisensory integration (De Gelder et al., 2003; Stevenson et al., 2017; Williams et al., 2010). A work in our group examined the audio-visual temporal integration with sound-induced flash illusion and found a lengthened temporal binding window for the bisensory information in SZs (Kim et al., IMRF 2017). The present study investigated the audio-visual spatial integration in schizophrenia by using the ventriloquist illusion paradigm. Ventriloquist illusion indicates biased perception of the spatial position of an auditory stimulus toward the position of a temporally synchronized visual stimulus. A group of 22 SZs and a group of 22 healthy controls performed an auditory localization task when a beep sounded with or without a synchronized LED flash. Eight loudspeakers with attached LEDs were arranged in a semicircular array, half of which were on the left, and the other half were on the right side of the central fixation LED. Each loudspeaker was 14-deg away from its adjacent one. The audio-visual stimuli were presented 0-deg, 14-deg or 28-deg apart. The ventriloquist effect was defined as the ratio of biased sound localization towards the visual stimulus to the spatial disparity between audio-visual stimuli. Following the experiment, SZs were given a structured psychiatric interview to assess the severity of positive and negative symptoms with SAPS and SANS respectively. Results showed a typical ventriloquist effect in both groups with no statistically significant difference. However, in SZs, the ventriloquist effect showed a negative correlation with the severity of visual hallucinations, and a marginally significant negative correlation with the global ratings of hallucinations. There was no correlation between hallucinations and unisensory auditory localization performance. These results demonstrate that hallucinations were implicated in reduced audio-visual spatial integration, which might be related to impaired multisensory processing, not unisensory processing.

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Poster Session D > Multisensory Processing 1 > Poster D20

The Asymmetric Switch Cost between Subitizing and Estimation in Tactile Modality

View Poster | Visit me in Gather.Town Osprey Room on Sunday 8:00 pm - 10:00 pm EDT

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Subitizing (with number of items less than or equal to 4) and estimation (with number of items equal to or larger than 5) are two types of strategies for rapid enumeration. Debate remains about the relationship between subitizing and estimation, and evidence is scarce from the tactile modality. The present study has developed a novel processing switching paradigm to assess costs in cognitive resources related to switching between the two processes. Participants were required to enumerate two sequentially presented arrays of tactile pins with the set size of each array either within or out of a predetermined subitizing range (1-3 tactile pins). We found a general task-dependent switch cost within a narrow temporal range- the first numerical processing significantly influenced the second numerical processing with stimuli-onset-asychrony (SOA) between the two events was 100 ms. Specifically, the error rate of the second enumeration increased, while the accuracy and the precision decreased, when the enumeration process switched between the two strategies (subitizing-estimation or estimation-subitizing), relative to no switch (subitizing-subitizing or estimation-estimation). At the same time, an asymmetry was observed on the accuracy and the precision— a switch from estimation to subitizing triggered a robust switch cost effect with larger magnitudes than a switch from subitizing to estimation did. Taken together, our results suggest that the relationship of subitizing and estimation in tactile modality is consistent with the findings in visual modality (Anobile et al., 2012; Burr et al., 2010). Specifically, there is an additional mechanism over and above the unitary estimation, manifests certain flexibility and only operates on small numerosities when attentional resources permit.

Poster Session D > Multisensory Processing 1 > Poster D21

Illusory body ownership of dynamic invisible body is not associated with multimodal changes in body perception

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Illusory body ownership to a virtual body is induced by synchronous movements of own body and the virtual body. This illusion can be induced by the synchronous movement of only the hands and feet (Kondo et al., 2018). Here, we examined whether the illusory ownership to the invisible body with the hands and feet was associated with changes in tactile spatial representations. Participants observed the virtual gloves and socks which moved synchronously or asynchronously with the participant’s movements in the first-person perspective through a virtual mirror in front of them. Then, participants made speeded elevation (upper vs. lower) discriminations of tactile targets presented to any of the four positions of the participant's abdomen (upper left, upper right, lower left, and lower right of the epigastrium), while trying to ignore the visual distractor presented at congruent or incongruent elevations in the empty space between the virtual hands and feet. Crossmodal congruency effect (CCE, difference between performance in incongruent and congruent conditions) becomes large when visual and tactile stimuli are perceived to be at the same spatial location. Therefore, we hypothesized that if the synchronized movements of virtual hands and feet induced the full body ownership to the invisible body, the CCE would be larger in the synchronous condition than the asynchronous condition. We found that, although the subjective illusory ownership to the invisible body was replicated, there was no difference in CCE between the synchronous and asynchronous conditions. These results suggest that the illusory ownership of the invisible body and CCE (spatial tactile representation) may be based on separate cognitive mechanisms. However, since the studies of rubber hand illusion and full body illusion indicate a link between bodily self-consciousness (ownership and self-location) and CCE, we need to investigate the difference between invisible and visible body ownerships in future study.

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Color, Light and Material

Poster Session D > Color, Light and Material > Poster D41

Blue light impairment on the speed of exogenous attention shift

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Exposure to blue light not only contributes to vision, but also facilitates cognitive functions such as alertness, vigilance, and working memory. However, most studies examined the blue light effect only on the central visual field. The blue light facilitation effect may be due to vigilance increment or focused attention improvement. The vigilance increment view predicts that there is a general facilitation on both central and peripheral visual processing; however, the focused attention improvement view predicts that blue light is detrimental to peripheral visual processing. To test these hypotheses, we adopted the clock paradigm (Carlson, Hogendoorn, and Verstraten, 2006) to estimate the speed of exogenous and endogenous attention shift. Participants fixated at the center with 10 running clocks in the periphery positioned in an imaginary circle. Three conditions were manipulated: the peripheral-cue condition, where the target clock flashed as an exogenous cue; the central-cue condition, where a cuing line was presented at the fixation point as an endogenous cue; and the baseline condition as the control, where the cuing line was presented as a probe to exclude the time cost of attention shift, followed by the flash of the target clock. Participants reported the time of the target clock when either the peripheral or the central cue was presented. The speed of attention shift was estimated by the time latency between true and reported cue-onset time. We conducted experiments with blue and green background lights in Experiment 1, and with high and low S-cone stimulated background lights in Experiment 2. Results showed that exposure to blue light slowed down the speed of exogenous attention shift and these results were not due to the sluggish property of S-cone processing. This study supports the focused attention improvement view and shows a new blue light “impairment” different from previous studies.

Poster Session D > Color, Light and Material > Poster D42

Difference analysis of visual brain response between natural light and traditional LED based on steady-state visual evoked potential (SSVEP) paradigm stimulation

View Poster | Visit me in Gather.Town Manatee Room on Sunday 8:00 pm - 10:00 pm EDT

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Display light source has an important influence on the eye health. In most of the work and life scenes, LED panel light source display is still the backbone of the market. The discrete spectrum and high intensity blue spectrum of LED light

source have been criticized. Therefore, this paper innovates the display screen with natural light source instead of LED light source (remove the backlight and keep a uniform light sheet), and compares the paradigm stimulation under natural light and LED light based on steady-state visual evoked potential (SSVEP). Finally, the difference analysis of human visual brain response is given. In this study, the subjects were asked to evaluate the different performances of natural light source and LED light source in the range of illumination (284.12lx-13508.76lx) and color temperature (4973k-8511k), subjective (NASA-TLX) and objective (α + θ band index, pupil diameter, amplitude and signal-to-noise ratio of SSVEPs). NASA-TLX shows that natural light source with the same brightness can significantly reduce the visual fatigue of the subjects. The α + θ band index and the amplitude and signal-to-noise ratio of SSVEPs indicate that led light source can decrease human visual perception sensitivity and deepen visual fatigue more than natural light source in long-term light source stimulation experiment. The data of pupil diameter show that compared with natural light source, LED light source can stimulate human pupil to adjust in a large range. Under the same objective factors, such as test time and stimulus paradigm, human eyes are more likely to feel tired. On the basis of this research, this paper proposes a new light source design idea, which combines natural light source and adaptive LED light source under the relevant illumination and color temperature. It provides a valuable reference for indoor work and life environment design and improving light environment satisfaction.

Poster Session D > Color, Light and Material > Poster D43

In search of early cortical mechanisms for color: individual variability in steady-state VEP amplitudes for hues sweeping around the isoluminant LM and S cone-opponent plane

View Poster | Visit me in Gather.Town Manatee Room on Sunday 8:00 pm - 10:00 pm EDT

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From retina to V1, chromatic mechanisms fall along two cone-opponent ‘cardinal’ axes (L-M, S vs. L+M). Is this coding propagated to early cortex? To explore possible hue-selective cortical responses, we examined individual variability in steady-state visual evoked potentials of 16 participants, using a flickering checkerboard whose color swept around the isoluminant hue circle at three chromatic contrasts (Kaneko et al., 2020). For each hue, intra-individual correlations (r) were strongest with hues at nearby angles, consistent with multiple channels. But there were multiple excitatory and inhibitory sidelobes (+, - correlations) at distant angles. Remarkably, at the highest chromatic contrast, six sidelobes were at 0 (red, +[L-M]), 30 (magenta), 120 (blue), 180 (teal, -[L-M]), 240 (green), and 300 (yellow) degrees. Nonmetric Multidimensional Scaling* of the dissimilarity matrix (1-r) estimated four significant components. The first 2 components’ loadings showed multiple + or – peaks that aligned closely with the 6 sidelobes: red vs. blue and green; teal and magenta vs. yellow and blue. The 2 additional components added 4 colors: 90 (violet, [+S]) vs. 150 (blue-green) and yellow; 270 (lime, [-S]) and magenta vs. blue-green, blue and 330 (orange). (Some components differed/shifted for ½, ¼ contrasts). If these 4 exploratory, unvalidated components represent cortical hue-selective mechanisms, then they show neither classic cone- nor unique-hue opponency, nor complementarity, nor simple narrowly tuned color channels. Rather, the 4 ‘mechanisms’ subserve ten physiologically primary hues, and each primary hue has +, -, and Ø interactions with the other 9 hues. Possible implications of a new chromatic coding model are discussed for chromatic induction and assessment of singe-cell tuning. (*NMMDS, compared to PCA/FA, is nonparametric [i.e., no linearity, metricity, or multivariate normality required of data or underlying components]; doesn’t force ‘simple structure’ on data generated by broadly tuned overlapping mechanisms; and needs fewer components to explain variability).

Acknowledgements: JSPS KAKENHI grant numbers JP18K13365, JP18H04995, and JP20H00597

Poster Session D > Color, Light and Material > Poster D44

The development of hue selectivity in human visual cortex

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Recent electrophysiological studies in primates and fMRI studies in human have indicated the existence of neurons in

the visual cortex that selectively respond to hues off the cardinal axes of cone-opponent color space (intermediate colors). However, it is unclear when and how the hue selectivity develops in the early developmental stage of the visual system. In the present study, we measured hue selectivity of brain activity in infants using steady-state visual evoked potentials (SSVEPs). Infants observed the reversals of a checkerboard pattern during the measurement. Half of the tiles of checkerboard were filled with the background hue (Equal Energy White) and the rest of them were filled with a test hue. Twelve test hues were chosen from a hue circle, which had a color contrast of ΔL = 8 % and ΔS = 80 % with respect to the background color, in an equiluminant plane defined by the cone-opponent color space (Macleod & Boynton, 1979). To yield SSVEP responses, the pattern flipped at 5 Hz during a 5 seconds testing trial. The test hue changed every second along the hue circle during the measurement. Fourteen 5-6-months old infants participated in the study. The SSVEP response amplitudes in infants were assessed by a model that assumes that the responses of intermediate hues are the sum of responses of two nearby cardinal mechanisms. Our results revealed that infant’s SSVEP responses were more likely to be dominated by cone-opponent representation, in contrast to adults’ SSVEP responses in which amplitudes were significantly larger in intermediate hues (magenta and lime-green; Kaneko, Kuriki & Andersen, 2020). Meanwhile, average SSVEP amplitude showed a biased response along the red/green cardinal axis, which is also different from adults. This bias could result from the faster development of red/green cardinal mechanism (Teller, 1998).

Poster Session D > Color, Light and Material > Poster D45

Comparison of fMRI Experimental Paradigm for Decoding Color Constancy

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An effective paradigm is key to explore the neural mechanisms behind color constancy (CC) using fMRI. Based on the principle of hemodynamics, we design a different paradigm containing a resting block to compare with the original one without the resting block (Bannert and Bartels, 2017 NeuroImage). The stimulus blocks consist of scenes containing two different color patches illuminated by three different illumination conditions. Two classification tasks are used to decode the color signals from the recorded fMRI signals when the subject is watching the stimulation blocks under these stimulus conditions. For the classification task within the illuminants (e.g., a model is trained on the fMRI signals to discriminate the blue or yellow patches under two illuminants and tested to predict the color of the patches under the similar illuminants), we found that the classification accuracy of fMRI signals in the V1, V2, V3, and V4 areas in the paradigm with and without a resting block are both significantly higher than the random level. However, for the classification task across the different illuminants (e.g., a model is trained on the fMRI signals to discriminate the blue or yellow patches under two illuminants (blue and yellow) and then tested to predict the color of the patches under the third illuminant (e.g., neutral)), only the classification accuracy of the fMRI signals of V2 and V4 areas in the new paradigm are significantly higher than the random level, but not the case without a resting block. The major results are that both V2 and V4 regions have the function of decoding CC, which is highly relying on the experimental paradigm used. The resting blocks can effectively separate the BOLD signals between the stimulation blocks so that the signals do not overlap and interact, which is more conducive to decode the neural mechanism of CC.

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Poster Session D > Color, Light and Material > Poster D46

Effects of the surface-undulation spatial frequency on perceptual highlight removal for lightness perception.

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Human lightness (albedo) perception is not necessarily accurate. Previous studies have shown that humans perceive object lightness based on the surface area excluding specular highlights, though this highlight removal performance varies depending on the surface reflective properties and shapes. The purpose of this study was to examine the image features that determine the ability to remove highlights for lightness perception by focusing on the effects of spatial frequency of surface undulations in psychophysical experiments. The stimuli were computer-graphics images of plate-like objects, in which the undulations of real plastic samples were reproduced. There were many conditions in the spatial frequency and amplitude of the undulations, the surface roughness, and illumination maps as experimental parameters. In each trial, a plane-like object (test stimulus) and a matte sphere (reference stimulus) were presented side-by-side on a display. The observer adjusted the lightness of the reference stimulus so that the perceived lightness was matched between them. The results showed that, roughly speaking, the perceived lightness was determined mainly based on the mean luminance of the test stimulus. However, the perceived lightness was lower than that expected from the mean luminance prediction especially on low roughness stimuli, suggesting the contributions of highlight removal. Thus, we defined the difference in the perceived lightness on the test stimulus from that on flat planes as the highlight-removal index. This index moderately correlated with the image luminance contrast from the stimulus images, especially when filtered by the contrast sensitivity function (CSF). However, when the CSF-filtered luminance contrast was smaller than a certain level, the highlight-removal index was fixed at zero even though the undulations on all test stimuli could be easily perceived. These results suggest that perceptual highlight removal for lightness perception requires much more detailed luminance patterns than those for shape perception.

Poster Session D > Color, Light and Material > Poster D47

What factors determine the effects of color on perceived gloss? -Helmholtz-Kohlrausch effect vs highlight-shading color contrast-

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Previous studies have shown that chromatic information on object images, such as chromatic difference between specular highlight and diffuse shading, enhances perceived gloss (“color-gloss effect”, hereafter). However, the mechanisms underlying this color-gloss effect is still unclear. Here we aimed to psychophysically elucidate perceptual and image factors which yield the color-gloss effect. In experiment 1, we measured perceived glossiness on images of colored objects with different diffuse reflectance and surface roughness. The object images were first created as achromatic images with a computer-graphics software, and then were colored with various hue chromaticity while luminance was unchanged. There were two coloring conditions: D condition and SD condition. In D condition only the diffuse components were colored, while in SD condition both the diffuse and specular components were colored. The glossiness was measured in a paired comparison experiment; two object images with different hues were simultaneously presented to the observer as stimuli, and the observer responded which object seemed glossier with a 2AFC manner. The preference scale values were estimated according to the Thurston’s case V model after the experiment. The results exhibited mainly three important characteristics: 1) the color-gloss effect was stronger in SD condition than D condition, 2) the color-gloss effect increased with diffuse reflectance and roughness in D condition even though they decrease color contrast between specular and diffuse components, and 3) the color-gloss effect largely differed across the hues in both D and SD conditions. To examine the cause of this trend across hues, we measured the Helmholtz-Kohlrausch (H-K) effects on different luminance, saturation and hue conditions in experiment 2, and found that the trend across hues in experiment 1 was moderately correlated with H-K effect. These results suggest the H-K effect, not the color contrast between the specular highlights and diffuse shadings, predominantly contributes to the color-gloss effect.

Poster Session D > Color, Light and Material > Poster D48

Temporal characteristics of the Craik–O’Brien–Cornsweet effect as revealed by high-speed motion correspondence

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In the Craik–O'Brien–Cornsweet effect (COCE), a central edge of an opposing pair of luminance gradients makes the adjoining regions with identical luminance appear to differ in brightness. Some have suggested that the COCE is mediated by cortical propagation processes pertinent to perceptual filling-in. While the COCE can be affected by contextual cues such as lighting direction, there is evidence that low-level mechanisms are involved in this illusion. The COCE requires a duration of 0.1 s (Dakin & Bex, 2003), or, if no backward masks were applied, 0.05 s (Masuda et al., 2011). We investigated the temporal characteristics of the COCE and how the induced brightness might be used to track apparent motion. Stationary gratings consisting of the COCE-inducing luminance pattern along a circle were presented frame by frame. The phase of each subsequent grating was shifted by a quarter, so that the apparent differences in brightness could determine the direction of rotation, whereas the physical edges of the luminance gradients couldn't. Immediately after the stimulus presentation, the stimulus region was covered by a stationary random-dot pattern as a mask. Participants were asked to report whether the perceived direction of the rotational apparent motion was clockwise or counterclockwise. The results demonstrated that the participants correctly judged the direction of the phase shift as the duration of the COCE stimulus increased. The direction was correctly judged when the duration of each frame was as brief as 0.06 s at optimal numbers of frames. The rate of correct responses increased with increasing number of frames up to 8 frames. These results indicate that the COCE involves a fast process taking less time than previously estimated on the basis of the filling-in hypothesis. We will discuss the perception and the temporal characteristics of the COCE in the context of visual motion processing.

Acknowledgements: Acknowledgements: Supported by KAKENHI 18H05523

Poster Session D > Color, Light and Material > Poster D49

Comparison of Asian countries on the brightness perception of facial skin influenced by skin hue

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Human skin color is one of the most common colors which we see in everyday life. The skin color distribution of young Japanese women has a trend that yellowish skin had higher lightness than reddish skin. On the other hand, it was shown that reddish skin appeared brighter than yellowish skin when both had the same lightness. (Yoshikawa et al., 2012). However, we showed the trend reddish skin appeared brighter is not common in observers in different countries, suggesting that the brightness perception of facial skin color is influenced by the diversity of skin colors and observers (VSS 2020). The present study investigated facial skin brightness perception among observers in four Asian countries: Thailand, China, Korea, and Japan. A young Japanese female face was used for the experiment. Test faces of four skin color shades were prepared, corresponding to the average skin colors of Japanese, Thai, Caucasian, and African individuals. A test image (with constant lightness but different hue angles) and a scale image (with the original hue but varying lightness) were presented side-by-side on a color-calibrated tablet display. Observers adjusted the brightness of the facial skin of the scale image to match that of the test image. Our result indicated that Japanese observers showed a trend that reddish skin appeared brighter than the yellowish skin, which was consistent with the previous study, but Thai, Korean, Chinese observers did not. This implies that the facial skin brightness perception of Japanese observers is not universal, and there is the influence of ethnicities, countries, or environments on the color perception of facial skin.

Acknowledgements: Acknowledgements: JSPS KAKENHI JP 16H01663 & 18H04183

Poster Session D > Color, Light and Material > Poster D50

Color and Emotion Associations in Dravidian Culture.

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Color is present all around us and its presence affects our perception. It can add excitement and emotion to our everyday life . Past psychological models reported emotional responses with color, but the Language is a factor which is linked to the culture and expressed verbally. In the current study, we investigated the cross-cultural associations between color and emotion among Dravidian's (Telugu, Tamil, Kannada, and Malayalam) language participants. A random sample of 60 participants in the age group of 19 to 40 years who are native to Dravidian culture were included. A standardized questionnaire of color and emotions was used in all four languages, by executing the face to face interview of participants. Observational and survey methods were used to collect the data. The variables of eight emotions such as love, sadness, fear, hatred, desire, happiness, jealousy and anger were considered and participants were asked to choose any colors from the listed i.e.; violet, blue, green, yellow, orange, red, white, black or to specify any other color that they associate most related to a specific emotion. We used binomial test's and likelihood ratios to understand the specificity of color and emotion associated. Confidence interval of proportions was compared to see the similar color and emotion association's significance. We emphasize that the emotions are most commonly associated with warm and shiny colors and the role of language display differences in color and emotion associations among a Dravidian culture of South India.

Poster Session D > Color, Light and Material > Poster D51

Painterly depictions of glasses display a stylized pattern of highlights

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For a painterly depiction to be convincing, the distal world does not need to be captured perfectly: a stylistic depiction that does not adhere to the statistical regularities found in the distal world can nevertheless be perceptually convincing. Understanding which highlight features are, or are not, required in order to trigger robust, convincing gloss perceptions is vital to understand human gloss perception. Here we study highlights on drinking glasses as depicted in paintings and compare these to their equivalent in photos. Four participants annotated highlights on drinking glasses in photos (n=55) and paintings (n=55). Paintings were sourced from the Materials In Painting (MIP) dataset, and photos were sourced from the COCO dataset. We found that highlights in paintings appear in a strong, stylistic pattern in the same canonical location(s), which was not found in photos. Furthermore, we found that highlights in paintings are less ambiguous, measured as annotator agreement. Spherical glasses (e.g., wineglasses) in paintings typically display a highlight on the rim in the top-left, and one caustic reflection in the bottom right. Conical glasses (e.g., martini glasses) typically display a stretched highlight from the top to the stem of the glass. For photographs we found that the highlights varied much in location and pattern. The current study is limited to a relatively small section of glossy objects but demonstrates the benefits of annotating highlights on a broader range of glossy objects, which can lead to a better understanding of higher level (pattern) cues for convincing material communication.

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Eye movements

Poster Session D > Eye movements > Poster D52

Inhibiting saccades to hands: High-level visual processes modulate oculomotor control

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In visual perception, human faces are detected efficiently: we look at them preferentially, while is it difficult to ignore them. While such preferential processing has been established for faces, little is known about potentially similar

processing of body parts such as hands. Oculomotor and related control mechanisms can be quantified by measuring eye movements toward and away from hands and faces (prosaccades and antisaccades). The study aimed to measure whether a bias for hands would be manifest in antisaccades with high error rates and long latencies, as reported for faces. This study used an eye-tracking method to compare saccades towards and away from images of hands, faces, bodies (without heads) and cars. Each trial presented a target stimulus (for example, an image of a hand) to the left or right of a central fixation mark (9 degree eccentricity), and a square on the opposite site. Depending on instructions, participants had to move their eyes either towards the target or away from the target (towards the square). 200 prosaccades and 200 antisaccades were tested. The difference between antisaccades and prosaccades in terms of latency and error rate was quantified as antisaccade cost. Antisaccade cost on latencies showed a significant main effect of stimulus type, with the cost for hands being higher than for whole bodies or cars, but lower than for faces. Similarly, a significant main effect of stimulus type was found for antisaccade cost on error rates. For hands, cost on error rates was higher than for whole bodies or cars, but lower than for faces. Because the antisaccade cost (on latency and error rate) is higher for hands than for whole bodies or cars, these findings suggest that hands benefit from similar preferential processing as faces (although to a lesser extent), reflecting a bias for hands in social perception.

Does the difference in cranial current path change the torsional impression and behavior Galvanic Vestibular Stimulation?

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Galvanic Vestibular Stimulation(GVS) affects a sense of equilibrium and produces vestibulo-ocular reflex(VOR). The VOR produces torsional impressions and eye movements. However, which does electrical current pathway produces VOR? How does GVS effects to VOR? These questions are unclear. As the cause of these, the vestibular system is formed by semicircular canals and otolith organs, and it has not been determined which of these two organs the GVS affects. In this report, we hypothesize that the electrical current through the otolith organ is an effective factor for eye torsion, and propose the electrical current path model as a resistance network. The model assumes three paths: horizontal left-right, horizontal front-back, and vertical, since electrical current in low frequency band pass only through foramen in the cranium. In this electrical current path model, the differential electrical current vertically penetrating the left and right otolith organs is an effective factor for eye torsion, and the phase of eye torsion changes depend on the direction of the electrical current. To verify the validity of this model, the amount of electrical current following each pathway is suppressed by adding percutaneous short-circuits to the otolith organs, and the mechanism of each electrical current pathway and its contribution to the amount of visual torsion is clarified, under 0.1~1Hz GVS condition. The results show that the transcranially connected short circuit changed the subjective report and behavior of eye torsion. These results support the hypothesis of our proposal. The electrical current path model is expected to improve the controllability of eye movements by GVS.

Acknowledgements: This research was supported by Grant-in-Aid for JSPS Fellows.

The mind’s eye: mind-wandering revealed by eye movement hidden Markov model

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With the development of modern technology and social media, notifications from our devices make concentrating on our goals of working and learning more and more difficult. It is thus crucial to identify mind-wandering, the phenomenon that

people sometimes think about task-unrelated things that can cause negative effects on learning and working efficiency. Since eye movements have been shown to be highly correlated with attention, the present study aimed to examine whether eye movement patterns can be used to categorize people who are more prone to mind-wandering. Participants performed the sustained attention to response task (SART) while eye movement data were recorded. The SART comprised of 25 trials (with one target as the no-go trial and 24 go trials) per block, and there was a total of 40 blocks. At the end of each block, participants were probed to subjectively rate their state of attention on a 7-point scale. By applying the eye movement hidden Markov model (EMHMM) to analyze eye movement data, we classified participants into two different eye movement patterns: the centralized-viewing pattern and the distributed-viewing pattern. Results showed that participants using a centralized-viewing pattern showed better task performances (higher d') compared to those using a distributed-viewing pattern to the target (the no-go trials). We also found that people who had a centralized-viewing pattern tended to rate themselves as more focused and had smaller reaction-time variability and fixation dispersion before the subjective-rating probe. These results suggest that people's mind-wandering traits can be differentiated by specific eye movement patterns. The current study highlights the connection between eye movements and attention, and also provides new insight in utilizing EMHMM to study attention. Our data is stored in the MM-SART database and can be accessed through the provided link (http://mmsart.ee.ntu.edu.tw/NTU_SART/download.html).

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Differentiating luminance, arousal, and cognitive signals on pupil size and microsaccades

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Pupil size reflects a proxy for neural activity associated with global luminance, arousal and cognitive processing. Microsaccades are also modulated by arousal and cognitive processes. Are the effects of arousal and cognitive signals on pupil size and microsaccades coordinated? We hypothesize that if pupil size and microsaccades are coordinately modulated by these processes, pupil size immediately before microsaccade onset, as an index for ongoing processing, should correlate with microsaccade responses during tasks that alter these signals. Here, we examine the relationship between pupil size and microsaccade responses in tasks that include variations in global luminance, arousal, and cognitive control. In Experiment 1, an emotional acoustic stimulus was presented under two different global luminance levels while the participants maintained fixation upon a central fixation point. Microsaccades that occurred during stimulus presentation were analyzed. Higher microsaccade peak velocities correlated with larger pre-microsaccade pupil responses. In contrast, pupil responses evoked by global luminance signals did not correlate with microsaccade responses. In Experiment 2, to examine cognitive signals related to voluntary saccade preparation, we used an interleaved pro- and anti-saccade task, in which subjects were instructed, prior to target appearance, to either automatically look at the peripheral target (pro-saccade instruction) or to suppress the automatic response and voluntarily look in the opposite direction from the target (anti-saccade instruction). Microsaccades occurred during saccade preparation instruction were analyzed, showing higher microsaccade peak velocities correlated with larger pre-microsaccade pupil responses in the anti-saccade condition. The present study provides evidence for a tight coupling between pupil size and microsaccade responses. Given the central role of the superior colliculus in microsaccade generation, these results suggest the involvement of the superior colliculus for the pupil arousal and cognitive modulations, but not for the pupil luminance modulation.

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Motion Perception 1

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Exploring and explaining properties of motion processing in biological brains using a neural network

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Visual motion perception underpins behaviours ranging from navigation to depth perception and grasping. Our limited access to biological systems constrain our understanding of how motion is processed within the brain. Here we explore properties of motion perception in biological systems by training a neural network ('MotionNetxy') to estimate the velocity image sequences. The network recapitulates key characteristics of motion processing in biological brains, and we use our complete access to its structure explore and understand motion (mis)perception at the computational-, neural-, and perceptual-levels. First, we find that the network recapitulates the biological response to reverse-phi motion in terms of direction. We further find that it overestimates the speed of slow reverse-phi motion while underestimating the speed of fast reverse-phi motion because of the correlation between reverse-phi motion and the spatiotemporal receptive fields tuned to motion in opposite directions. Second, we find that the distribution of spatiotemporal tuning properties in the V1 and MT layers of the network are similar to those observed in biological systems. We then show that compared to MT units tuned to fast speeds, those tuned to slow speeds primarily receive input from V1 units tuned to high spatial frequency and low temporal frequency. Third, we find that there is a positive correlation between the pattern-motion and speed selectivity of MT units. Finally, we show that the network captures human underestimation of low coherence motion stimuli, and that this is due to pooling of noise and signal motion. These findings provide biologically plausible explanations for well-known phenomena, and produce concrete predictions for future psychophysical and neurophysiological experiments.

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Poster Session D > Motion Perception 1 > Poster D82

Dynamic presentation boosts the Ebbinghaus illusion but eliminates simultaneous contrast and Muller-lyer

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Mruczek et al (2015) showed that a dynamic version of the Ebbinghaus illusion almost doubles in strength compared to the standard version. In their dynamic version, the size of the surrounding inducers was modulated between large and small over about 1 second and the whole stimulus was also made to drift during the surround modulation. We explored many simultaneous contrast and geometric illusions and found no increase from dynamic presentation in any that we sampled. Here we report only the results for simultaneous orientation contrast and Müller-Lyer and surprisingly, when these two illusions were presented dynamically, their effects were actually eliminated. It is not yet clear why only these Ebbinghaus illusion increases with dynamic presentation. We offer the same explanation that Mruczek and colleagues proposed (2015) – with static presentation, information about actual size and position accumulates from the receptive fields at that location. When the illusion figures are dynamic (moving or flashed), however, individual receptive fields cannot accumulate the corrective information and the illusion strength is less constrained. This hypothesis does not account for why orientation contrast and the Müller-Lyer illusions are eliminated as opposed to amplified.

Poster Session D > Motion Perception 1 > Poster D83

A motion-energy-based optimization method for generating an image sequence causing four-stroke apparent motion illusion

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Four-stroke apparent motion (FSAM) is a phenomenon in which the repetition of a four-image sequence creates the illusion wherein an object in the sequence is moving in a single direction. Usually, the illusion is produced by playing two consecutive frames followed by two frames with the negative and positive sides of luminance polarity reversed (Anstis &

Rogers, 1986; Kawabe et al. 2019). On the other hand, methods to generate image sequences that can induce FSAM through image optimization have not been investigated. In this study, we propose a method to generate images inducing FSAM by image optimization based on the motion energy model (e.g., Adelson & Bergen, 1985). In particular, using the model of V1 complex cells that output motion energy from two images in the first and second images, we optimized the third and fourth images so that the motion energy between the second and third images, the third and fourth images, and the fourth and first images was equalized to the motion energy between the given first and second images. The outcome of the optimization procedure contained the negative-positive reversed version of the first and second images, and FSAM was observed by repeatedly playing back the sequence with original and optimized image pairs.

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Adaptation to an illusory aspect ratio distorted by motion patches in a deformation vector field

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A stationary Gaussian envelope of a Gabor patch that contains a moving carrier is perceptually shifted in the direction of the motion, referred to as motion-induced position shift (MIPS). When such motion patches are arranged to comprise a diamond-shaped constellation with a physical aspect ratio of 1:1 and moved according to a particular deformation vector field, the MIPSs produced in these patches make the diamond as a whole appear to be distorted vertically or horizontally. Previously it has been reported that adaptation to such perceptually distorted diamonds consisting of many motion patches produces a figural aftereffect (FAE), suggesting that the process responsible for our shape perception about aspect ratio utilizes positional cues coming from motion processing. To clarify the contributing factors for the above phenomenon, here we investigated whether the FAE requires a specific constellation, motion patches, or a motion vector field. In an experiment, we removed the diamond constellation so that motion patches were randomly arranged in space, losing a diamond shape, whilst keeping the occurrence of MIPS and a deformation vector field to induce perceptually vertical or horizontal distortion. In another experiment, we removed both the diamond constellation and patchy configuration, whilst keeping only a random-dot pattern moved according to a deformation vector field. The results indicated that the constellation distorted by the MIPS produced in motion patches and the deformation vector field were needed for the FAE to occur. Our studies are the first to show relationships between a deformation vector field in motion processing and the shape processing about aspect ratio perception. We will discuss the effects of motion processing on shape processing, especially focusing on how position representation affected by motion processing is utilized in shape processing and how the computation based on a vector field in motion processing changes aspect ratio processing.

Acknowledgements: Supported by KAKENHI 18H01099

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The flash grab effect into the blind spot

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The flash grab effect refers to the phenomenon in which a flashed bar superimposed upon a moving pattern at its directional reversal appears to be shifted in the new direction, as if the flash is grabbed by the reversed object, which appears to have reversed well before the actual reversal (Cavanagh & Anstis, 2013). This effect is deemed to require attention and conceivably involve high-level localization mechanisms. If the high-level account is true, the mechanism should have access to positional representation that has already taken care of image imperfections stemming from the retinal structure, such as the blind spot. The blind spot is the region corresponding to the optic disk on the retina where no rods/cones exist, so some computation is required to enjoy a seamless visual world despite the lack of visual inputs there. This study examined whether the flash grab effect occurs for a flashed bar presented just outside the blind-spot border such that the bar is grabbed by a reversing pattern and dragged into the inside of the blind spot. In a control condition, the bar at the same location was flashed just when the moving pattern reversed its direction to grab the bar away from the blind spot. In further control conditions, the flash location was far away from the blind spot, or the flash onset time was far away from the directional reversal time of the moving pattern; when the flash onset did not coincide with it, another illusion called the flash drag effect was also expected to occur. In all conditions, we confirmed illusory position shifts in line with the flash grab, or drag, effect, thus we found an illusory position shift into the blind spot due to the flash grab effect. Our results support the claim of high level position processing requiring attention.

Acknowledgements: Supported by KAKENHI 18H01099

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Metacognitive adaptation revealed in serial dependence of visual confidence judgments

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Confidence judgment on one visual task can influence the confidence on the following task, a phenomenon known as “confidence leak” (Rahnev et al., 2015). However, little is known about the metacognitive mechanisms underlying this serial dependence in confidence judgments across multiple trials. In the present study, we investigated the mechanisms underlying the serial dependence of visual confidence using random-dot motion patterns as stimuli. On each trial, observers discriminated the motion direction (left or right) and rated their confidence in their direction-discrimination response on a 4-point scale. Task difficulty was controlled by varying motion coherence and was calibrated to each observer’s direction discriminability. Trials with medium difficulty level (target trials) were always preceded by either one or two consecutive trials that were either easy or hard (i.e., hard-medium, hard-hard-medium, easy-medium, easy-easy-medium, etc.). In Experiment 1, we found that confidence ratings for target trials (perceptual performance matched) were higher when these trials were immediately preceded by easy trials than by hard trials. In Experiment 2, this serial-dependence effect disappeared when observers rated the motion speed (a non-confidence response) in the immediately-preceding trial. In Experiment 3, the serial-dependence effect remained minimal even when the motion speed in the preceding trial was manipulated to enhance motor priming effect. We compared candidate models that updated decision criteria through different processes. Model evidence was higher 1) when decision criteria were updated based on a template set of criteria on every trial (template-updating models) than when criteria were updated based on those used in recent trials (serial-updating models), and 2) when considering only explicit confidence ratings from preceding trials and ignoring implicit confidence estimates in non-confidence, speed-rating trials than when considering both. Our findings suggest that the metacognitive system is adaptive in response to recent task and response history.

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Poster Session D > Motion Perception 1 > Poster D88

The effect of high fps on vision in visual presentation under active motion

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In conventional video presentation system, 24-60 fps has been widely used because high fps is considered indistinguishable by humans. However, it has often been pointed out that there is a lack of reality under the fps in VR where the user's viewpoint moves. This may be because of the effect of lowering the perceptual stimulus threshold by active motion of the viewpoint. In fact, we have confirmed that the subjective resolution differs by changing the frame rate when binary images are presented in front of the eyes under active motion viewing. Therefore, we observed the binary images fixed in front of the eyes during lateral head movement using 60 fps and 1440 fps presentation fps. We then identified this effect by measuring contrast acuity using equivalent acuity judgment. The method of the experiment is to present a binary image on a screen prepared in front of the eyes, and to draw the image by moving it at the same speed as the head movement. After the image was presented, the gray image was presented once. After the image was presented, the gray image was presented once. After the images were presented, the gray image was presented once,

and then the subject was asked to respond by adjusting the contrast using equivalent acuity judgment. The subjects tended to respond with lower Michelson contrast when the images were presented at 1440 fps compared to 60 fps. This perceptual difference indicates that high fps presentation, which is previously considered unnecessary because people can't distinguish from 60 fps presentation, could present visual information more clearly in visual presentation during active motion.

Poster Session D > Motion Perception 1 > Poster D89

Differences in virtual and physical head orientation predict sickness during head-mounted display based virtual reality

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When we rotate our heads during head-mounted display (HMD) based virtual reality (VR), our virtual head tends to trail its true orientation (due to display lag). However, the exact differences in our virtual and physical head pose (DVP) vary throughout the movement. We recently proposed that large amplitude, time varying patterns of DVP were the primary trigger for cybersickness in active HMD VR. This study tests the DVP hypothesis by measuring the sickness, and estimating the DVP, produced by head rotations under different levels of imposed display lag (from 0 to 200 ms). On each trial, users made continuous, oscillatory head movements in either yaw, pitch or roll while seated inside a large virtual room. After, we used the level of imposed display lag for the condition, and the user's own tracked head-motion data, to estimate their DVP time series data for each trial. Irrespective of the axis or the speed of the head movement, we found that DVP reliably predicted our participants experiences of cybersickness. Significant positive linear relationships were found between the severity of their sickness and the mean, peak and standard deviation of this DVP data. Thus, our DVP hypothesis appears to offer significant advantages over existing (general) theories of motion sickness in terms of understanding user experiences in HMD VR. Instead of merely speculating about the presence, or degree, of sensory conflict in a particular simulation, DVP can be used to estimate the conflict produced by the active HMD VR. Importantly, this DVP is an objective measure of the stimulation (not an internal model of the user's sensory processing). Compared to its many competitors, DVP also appears to provide a simpler operational definition of the provocative stimulation for cybersickness (since it is focussed only on movements of the head; not the body or limbs).

Acknowledgements: ARC Discovery Project: DP210101475

Poster Session D > Motion Perception 1 > Poster D90

Creation of a new vection total index calculated by new individual models of latency, duration and magnitude of vection.

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When the coherent motion stimulus is presented in a very wide field of view, the observer would perceive an illusory movement of the self-body. This visually induced self-motion is named “vection” (see review, Palmisano et al., 2015). In this study, we proposed a mathematical model that revealed the relationship between vection strength and the amount of the activities of the V1 cells by motion energy (e.g. motion energy model by Adelson & Bergen, 1985). Our model was based on the previous results in the study by Fujii et al. (2018). Three indices, i.e. latency, duration, and magnitude, have been repeatedly used for knowing the vection strength (Seno et al., 2017 & 2018). Fujii et al. (2018) revealed the relationship between the frame rate and those three vection indices, and considered the relationship between vection and the motion energy calculated by the frame rate, i.e. the more the frame rate, the more the motion energy. We further considered and elaborated new mathematical models for each vection indices. We reached the fact that the individual mathematical model of each vection index could all be expressed in a similar functional form, i.e. the exponential function. We finally could propose a new vection index (vection strength variable), which integrated all three indices and create a total evaluation value of vection strength. This new variable enables us to know the real vection strength even

when the three indices are inconsistent. Two demonstrations to show the effectiveness of our model and the new index, made by using two previous published data were explained in detail in this poster (Mori & Seno, 2018; Seno, Kiyokawa & Abe, 2013). The goal of this study is to translate the subjective vection strength into the amount of activations of V1 cells, as more objective values.

Poster Session D > Motion Perception 1 > Poster D91

Comparison of the features of visual vection with those of cutaneous vection

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We examined differences in the characteristics of visual and cutaneous vection (sensation of illusory self-motion in the absence of physical movement). In experiments, we measured the latency of vection from the beginning of visual and non-visual stimulation. In Experiment 1, we compared the effects of vestibular sensory stimuli upon the visual vection with those upon the cutaneous vection. Velocity of wind as a cutaneous stimulus ranged from 0.6 to 5.5 m/sec by the use of air multiplier while the visual stimulus was expansion of 4,000 random dots on a flat display ranged from 37.5 to 114.3 arc deg/sec. Vestibular stimulus was vibration of the horse-riding simulator which corresponded to a horse walk with a velocity of 1.78 m/sec. The latencies of both visual vection and cutaneous vection were well fitted to positive quadratic functions of velocity of wind or optical flow, respectively. We found obvious difference of the shortest latency between the visual vection (8.0 sec) and cutaneous vection (31.0 sec). In Experiment 2, we examined the effect of vestibular stimulus on visual vection and cutaneous vection. Vestibular sensory stimuli were movement of a ride with velocity of 0.95 cm/sec. Velocity of wind as a cutaneous stimulus was fixed at 3.0 m/sec while the visual stimulus was expansion of 2,000 random dots on a flat display with 132.3 arc deg/sec. We found that the latency of the visual vection (8.2 sec) was significantly shorter than that of cutaneous vection (22.1 sec) without vestibular stimulation while there was not significant difference in latency between the visual vection (7.5 sec) and cutaneous vection (5.6 sec) with vestibular stimulation. These results suggest that some common mechanisms underlie the visual vection and also non-visual vection while contribution of each modality on vection varies with velocity of multisensory stimulus.

Acknowledgements: This work was supported by JSPS KAKENHI Grant Number JP40837465.

Poster Session D > Motion Perception 1 > Poster D92

Stimulus meaning can alter vection strength

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Vection is dominated by retinal image motion of the static external scene. If object motion is perceived, rather than environment motion, vection is not strongly induced. Previous research has indeed suggested that the allocation of motion to the object can typically occur for meaningful stimuli, such as feathers, petals or leaves, which cannot induce stronger vection. However, still few studies have focused on this relationship between stimulus meaning and vection. The present study examined how and whether stimulus meaning influences vection by using more informative meaningful animations. In Experiment 1, we presented 9 movies to the participants consisting of two lines of cars (with or without wheel rotations) that moved forward, backward, or upward. Each movie lasted for 30 seconds. We also presented inverted cars and black ovals that moved forward as control conditions. In Experiment 2, we further investigated the effect of the meaning of the background added to the moving cars. We presented 6 movies consisting of two lines of cars that moved forward with a static background or a moving background in the same or opposite direction. Participants were required to press the button if they were perceiving vection and rated the subjective vection strength by using a 101-point rating scale. The results of Experiment 1 showed that in conditions with forward- and backward-moving cars, vection was stronger than in conditions with upward-moving and inverted cars. The results of Experiment 2 showed that vection became the weakest in the static background condition and that the cars' wheel rotations could facilitate vection. We thought that the more natural the stimulus meanings were (forward- and backward-moving cars), the stronger the vection was, following the "naturalness-hypothesis" (Nakamura, 2013). The relationship between the

effects of stimulus meaning and naturalness on vection should be further examined in the future.

Poster Session D > Motion Perception 1 > Poster D93

Subjective colorfulness and preferred color facilitate vection.

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The colors might be special for self-motion perception and vection. There is still a controversy about the different effects of different colors on vection strength. In the present study, we investigated whether the subjective colorfulness, the numbers of colors, the types of motion stimuli and the color preferences, could modify vection strengths respectively.For the subjective colorfulness, we employed two experiments by using two types of motion stimuli (EXP1; expanding circular grating and EXP2; expanding dot optic flow). Color conditions (red, blue, purple, yellow, brown, pink, green, and white and also high, middle, low saturations respectively) which were conducted randomly. The participants were asked to press a button while they were perceiving vection, rate the vection strength and subjective colorfulness (both 0 to 100) after each trial. In Experiment 1, vection became the strongest in the control (black and white) condition. However, the subjective colorfulness correlated with magnitude positively. Experiment 2 showed that the effects of color and the subjective colorfulness had a much weaker effect than that in Experiment 1. These results suggest that colors have a significant effect for vection induction. Colored stimuli might inhibit vection. However, the subjective colorfulness has a positive enhancing effect on vection at the same time. For the color preferences, we employed the dot optic flow colored in seven different colors (red, green, blue, purple, pink, brown and yellow). The participants were asked to rate the vection strength and also the color preferences (both 0 to 100) after each trial. The result showed that the subjective color preference significantly correlated with three vection indices positively. The preferred colored vection stimuli could induce stronger vection. In conclusion, colors had significant effect on vection strength.

Poster Session D > Motion Perception 1 > Poster D94

A picture book that causes vection and that ratings.

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Vection is an illusion of self-motion perception. Recently, vection is utilized in various places, e.g. amusement parks, movies, VR environments, and Games as a digital content. On the contrary to the vection as a digital content, we newly focused on vection as an analogue content. We made a picture book of vection and evaluated it in this study. For making a picture book, we first surveyed the history of vection from 19 century to mid 20 century and knew that there are various analogue contents of vection in the past. In a pilot study, we confirmed that four types of static visual illusions invented by Prof. Akiyoshi Kitaoka that could induce vection. We chose the best illusory static image that could induce enough strong vection and made a picture book based on that illusory image. Twenty-five couples of a parent and a child read that picture book and we recorded those whole behaviors of those couples. There were three conditions in the experiment of the picture book. First, a picture book with self-motion illusion. Second, a picture book without self-motion illusion and as the third condition, a picture book with self-motion illusion with an instruction “this is a picture book of a self-motion illusion”. The time consumed in the page of the self-motion illusion was larger in the condition of self-motion illusion with the instruction. Also, the uttered words related with the self-motion perception were increased in this condition. Thus, we could confirm that vection was highly induced in the condition of self-motion illusion with the instruction. We found the high possibility of the picture book of vection, i.e. the high possibility of vection as an analogue content, even though there should be a lot of improvements.

Poster Session D > Motion Perception 1 > Poster D95

Three vection studies from a view point of multimedia

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[1] [1] [2] [1] [2]

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Visually induced illusory self-motion perception is named "Vection". The application of vection in VR environments, amusement parks and movies has been increased significantly. We conducted three studies about it. First, to know the ordinary people's knowledge of vection, we conducted a questionnaire to 2147 persons and revealed some aspects who know vection and who do not know it. The characteristics of people who know vection are, more men than women, more annual income, and more knowledge of IT and Psychology. There is no significant difference in age, life satisfaction, self-evaluation and daily audio-visual time and in their occupation. Second, we investigated the effect of the Auto-stereo visual display, i.e. Looking Glass, comparing to the common non-stereo TV display. We set up three conditions, 2D and 3D Looking Glass and 2D TV. Two speeds of optic flow were employed. The results showed that the small auto-stereoscopic display device could induce strong vection like a large TV display. Third, a virtual movie theater was created in the university and examined whether the different positions in the theater could induce vection differently. The results showed that participants could perceive the strongest vection in the center of the front row. In the case of the same screen distance, the left or right position has little effect. The heights of the participants did not change the intensity of the vection. Previous studies have extensively examined the stimulus parameters for effective vection induction. Our three studies could be thought as the application research of vection and created a new trend in vection.

Poster Session D > Motion Perception 1 > Poster D96

Correlation analyses between various aspects of human life and vection strength

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Vection is visually induced illusory self-motion perception. In previous vection studies, negative correlation with narcissistic personality (Seno et al., 2011) and positive correlation with the field dependence (Keshavarz et al., 2017). Also emotional valence could modify vection strength (Valjamae & Seno, 2016). We thought that these properties should be highly related to various aspects of human life. Thus, in this study, we investigated whether there are significant correlations between vection (latency, duration and magnitude) and various aspects of human life, e.g. clothing costs, self-estimated fashion sense, future child number, Psychopathy, looking attractiveness. Vection was induced by an expanding circular grating in a darkened chamber. This vection stimulus was previously used in our study (e.g. Seno et al., 2018). Before conducting the vection experiment, by using an online questionnaire, we obtained the 4 items about human life, i.e. ideal child number, sense of fashion, the costs of clothing and how much they love children, also we made the participants answer the Hare Psychopathy checklist (Hare, 1991 & 2003). 22 (11 males and 11 females) participated (ranged 21 to 30 years old) in this study. The results showed that substantial strong vection was induced in all participants. We found some significant correlations between looking attractiveness and vection duration, between vection latency and vection duration and between ideal child number and likeness of children. Also, there were some tendencies of significant correlations between likeness of children and vection magnitude, looking attractiveness and vection latency, and between vection duration and Psychopathy tendency. We can say that vection strength can be affected by some human personalities and characteristics. We newly hypothesized and speculated from these results that vection is mediated by "empathy" and the acquiring the perspective of others. We will explain this in the poster more in detail.

Spatial and Temporal Vision

Poster Session D > Spatial and Temporal Vision > Poster D97

Four-dimensional energy spectrum model of natural texture perception

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Texture information plays a critical role in the immediate perception of scenes, objects, and materials. Past studies on

human texture vision have postulated two major models following Julesz's conjecture that the visual system discriminates textures on the basis of low-level image statistics. The filter–rectify–filter (FRF) model explains a range of psychophysical data on texture segregation by assuming second-order filtering that extracts spatial variations in the energy output of first-order filters tuned to the spatial frequency and orientation. The Portilla–Simoncelli (PS) texture-statistics model describes, and synthesizes, the perception of natural textures by assuming multiple classes of image statistics, including moments, subband energy, and auto-correlation in subband energy across position, orientation, and spatial frequency. The two models may appear to be largely different from each other but are so only in mathematical expression. Given that the power spectrum is a Fourier transform of the auto-correlation function, high-level PS statistics (auto-correlations) can be expressed as a four-dimensional (x–y space / orientation / spatial frequency) energy spectrum, and this representation is equivalent to a four-dimensional extension of the FRF model in the Fourier domain. On this basis, we unify the two theories to propose a conceptually simpler model whereby texture perception is described only by the luminance spectrum and the four-dimensional energy spectrum (+ pixel moment statistics). To verify this model, we synthesized 'energy-phase randomized (ePR)' images for a variety of natural textures (>300 images, such as images of leaves, gravels, and fabrics), in the same manner as classical luminance phase randomization. Only the pixel skewness was finally matched to the original. Our psychophysical experiments of similarity rating and peripheral discrimination clearly showed that the ePR images perceptually mimicked the original natural textures with a high quality comparable to that of PS synthesized images.

Poster Session D > Spatial and Temporal Vision > Poster D98

A computational model to predict the visibility of alpha-blended images

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Alpha blending is often used as a means of semi-transparently rendering an image over another background image. However, this blending technique has a problem in that the visibility of the blended foreground image depends on the background image. In particular, if the background contains a high-contrast texture, the visibility of the foreground image is greatly impaired by contrast masking. Therefore, it would be desirable to be able to adaptively adjust the blending parameter (alpha) to compensate for the masking effect. For this purpose, a model that can predict the visibility of alpha-blended images is necessary. In this study, we tested the effectiveness of early spatial vision models that can explain contrast masking as candidates for the prediction model. As experimental stimuli, we used alpha-blended images generated from various types of images such as textures, natural scenes, and artworks. The visibility matching task was used to measure visibility, where the participants matched the visibility of the foreground patch in the test image to that of the reference by adjusting the alpha value of the test image. There were two types of conditions: matching between images with the same foreground patches and matching between images with different foreground patches. 2000 different combinations of image patches were used for each condition. As a result, we found that the conventional spatial vision model could not predict the matching data well. To explain the data, we propose a content-adaptive feature aggregation mechanism which adaptively weights image features, such as spatial frequency and color information, based on the original appearance of the foreground image when aggregating those features into a single visibility level. We will show that this adaptive weighting mechanism is important for accurately predicting the visibility of arbitrary images through ablation studies.

Poster Session D > Spatial and Temporal Vision > Poster D99

White matter microstructural properties in glaucoma: multi-contrast magnetic resonance imaging study

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5

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Glaucoma is a disorder causing visual field loss as a result of retinal ganglion cell damage. Previous diffusion-weighted MRI (dMRI) studies demonstrated that retinal ganglion cell damage affects tissues in the optic tract and optic radiation (Nuzzi et al., 2018). However, since previous studies used the diffusion tensor model to analyze dMRI data, the microstructural interpretation of white matter tissue changes remains uncertain. Here, we used a multi-contrast MRI approach to clarify the type of microstructural damage occurring in glaucoma patients. We collected multi-shell dMRI data from 17 glaucoma patients (mean age = 56.6, 8 females) and 30 controls (mean age = 51.4 years, 14 females) using a 3T SIEMENS MRI scanner. We also collected quantitative T1 (qT1) data (Mezer et al., 2013), which are considered to be relatively specific to myelin, from all participants. We analyzed dMRI data using neurite orientation dispersion and density imaging (Zhang et al., 2012) to estimate three types of tissue property metrics (intra-cellular volume fraction, [ICVF]; orientation dispersion index, [ODI]; isotropic volume fraction, [ISoV]). We identified the optic tract and optic radiation using tractography (Sherbondy et al., 2008). In the optic tract, we found significant differences between glaucoma patients and controls for all metrics (d’ = -0.99, 1.40, -1.71, and 1.40 for qT1, ICVF, ODI, and ISoV; P < .005 in all cases). In the optic radiation, we only found significant inter-group differences in ICVF (d’ = 1.13; P < .001), not in others (d’= -0.06, -0.42, 0.19 for qT1, ODI, and ISoV; P > .1 in all cases). ICVF in the optic radiation significantly correlated with the visual field test (R = 0.50, P = 0.04). Our results suggest that tissue changes in the optic radiation might be explained by axonal damage affecting intracellular diffusion signals, rather than myelin damage.

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Poster Session D > Spatial and Temporal Vision > Poster D101

Temporal synchrony accompany with structure cue is more effective in the segmentation task

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The visual system uses not only spatial but also temporal cues to segregate objects from their background. Such temporal cues include temporal synchrony (timing of changes, e.g., temporal lag) and temporal structure (pattern of changes over time) between the figure and ground. In this study, we investigated how these two factors interacted and influenced the segregation performance. A 4-by-4 lattice composed of discs with randomly assigned contrast was used, and the temporal properties among the alternating rows or columns were the same. The participants were required to determine whether the lattice consisted of horizontal or vertical bars. Four levels of temporal frequency (2, 4, 6, 8 Hz) and various temporal lags were adopted. In Experiment 1, the temporal delay between the column/row was varied and the temporal structure was kept the same; whereas, in Experiment 2, the temporal lag was jittered, with the timing of the changes either leading or lagging so that the temporal structure was different but the temporal lag was the same locally. The results showed that the optimal correctness rate decreased with the increase of temporal frequency in Experiment 1 but not in Experiment 2; also, Experiment 2 performed better than Experiment 1 (correctness rate: 0.85, 0.95). The discrimination thresholds—defined as the midpoint between the low and high plateau—showed similar temporal lag thresholds (31.96 ms ± 0.25; 25.32 ms ± 0.42) for each frequency in both experiments. In conclusion, temporal synchrony (lag) is an important factor for temporal segmentation tasks and is determined by the absolute time difference. However, the temporal structure (Experiment 2) could facilitate the segregation performance.

Poster Session D > Spatial and Temporal Vision > Poster D102

Temporal characteristics of bandpass noise that cause visual unpleasantness

View Poster | Visit me in Gather.Town Dolphin Room on Sunday 8:00 pm - 10:00 pm EDT

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Increasing psychophysical evidence shows that static images with a specific spatial frequency and orientation spectrum give rise to a feeling of discomfort or unpleasantness. Humans also have unpleasant feeling toward dynamic images such as a movie of swarming worms. However, it is largely unknown how dynamic information affect visual unpleasantness of a spatially patterned image. Here, we examined the unpleasantness rating of static or dynamic visual noises with variable spatial frequencies (0.3 - 5.3 c/deg), temporal frequencies (0 - 15 Hz), temporal frequency bandwidths (1, 2, or infinite deg), and orientation bandwidth (30, 90, infinite deg). The results showed that static noises with narrow spatial frequency bandwidth and with wide orientation bandwidth were rated significantly unpleasant, replicating the previous data (Ogawa & Motoyoshi, 2020, Front. Psych.). Moreover, we found that dynamic noises with relatively low temporal frequencies (0.5 - 2 Hz) appeared even more profound than the static noises regardless of the spatial property. However, translational motion of the noise had no effect on the unpleasantness rating at all. A subsequent experiment with a spatially band-passed global motion display demonstrated that slow motions with variegated directions was a crucial factor for the enhanced unpleasantness in a dynamic stimulus. Given that in the natural environment, image features inside a moving object tend to move in a coherent direction, the present results further support the notion that humans tend to feel unpleasantness toward visual stimuli that deviate from the statistical regularity of natural scenes.

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Averaging performances of orientations decrease in proportion to depth increase

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Our research aims to find out how deep a visual field is operated for integration of orientations as an ensemble. Ensemble perception is a process that the visual system produces summary statistical representations from any feature. Here we focus on the feature of orientations that is one of the most primary visual characteristics involved in the configuration of objects. The current research investigates integration process of grating orientations in a virtual three-dimensional space using a stereoscope, which could give us a clue to the depth affecting on convergence of the orientations under the size constancy situation. Gratings were defined with 0.5 cycles per degree on the standard picture plane (the physical screen) and a radius of the presentation area was fixed with five degrees of visual angle, irrespective of the depth, but they had apparently never overlapped one another. Eight gratings were randomly presented from the standard picture plane to 100 cm maximum depth and these gratings randomly oriented varying 0.5 degrees to 32 degrees from the average of each trial. After 100 ms presentation of the set, participants indicated to which side it tilted compared to the vertical with two-alternative forced choice. Our results showed that sensitivity to the orientation variance increased in proportion to the depth increase despite the size constancy, suggesting that employed total space had influenced on averaging performances about orientations. For ensemble perception, human visual system does not always integrate all orientation information with the same sensitivity regardless of depth.

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Poster Session E > Visual Memory: Working, long-term 2 > Poster E1

Category labels do not improve working memory performance for ambiguous shapes

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Visual working memory capacity is greater for meaningful objects (e.g., trees) than both simple features (e.g., colors) and visually-matched meaningless stimuli (e.g., scrambled trees; e.g., Brady & Störmer, 2020). Here, we tested whether adding labels to ambiguous shape stimuli during encoding would improve subsequent memory performance for objects from the same category. Participants were shown three ambiguous shapes made from objects of the same category (e.g., three watches) for 1000ms, followed by a short delay period (1000ms) and a 2-AFC within-category discrimination test. In Experiment 1 (N=200), the shapes were black silhouettes of familiar objects that have been shown to be more recognizable when labels are provided (Koutstaal et al., 2003). In Experiment 2 (N=200), the shapes were warped images of real-world objects that were distorted just beyond recognition using the diffeomorphic scrambling technique (Stojanoski & Cusack, 2014). On each trial, half of the participants were prompted to “remember these shapes” and the other half were shown a category label (“remember these trees”) that could help participants recognize the shapes. In order to ensure participants did not rely on verbal strategies to perform the memory task itself, they rehearsed four digits out loud throughout each trial. Although we predicted the group that received the category labels would have better memory performance than the group that did not receive labels, memory performance (d’) did not differ between groups in Experiment 1 (p=.37; BF01=4.35) or Experiment 2 (p=.60; BF01=5.72). This suggests that providing labels to support recognition of ambiguous shape stimuli during encoding does not allow them to be memorized with enough additional detail to improve subsequent within-category discriminability. In future work, we will test whether providing category labels improves memory performance for a within-category discrimination test when the memory set consists of more distinct objects (from different categories).

Acknowledgements: NSF grant (BCS-1829434)

Poster Session E > Visual Memory: Working, long-term 2 > Poster E2

Interactions between items within working memory overpower biases from recent history and long-term category priors

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Items maintained in working memory cannot be studied independently; memories are biased by other information, like long-term priors (e.g., color categories: Bae et al. 2014), recent history (e.g., serial dependence, Fischer & Whitney, 2014) and the other contents simultaneously maintained in working memory (e.g., repulsion biases and ensembles; Chunharas et al. 2019). To examine the relative strength of these sources of bias by amplifying them, we implemented a within-subject iterated-reproduction paradigm (the reported color from trial N would be used as the stimulus in a later trial e.g., trial N+20). In Experiment 1 and 2, a single color was remembered and reported on a color wheel. Experiment 1 found that the drift in the reported colors within-subject (t=6.0, p<0.001) was influenced by color categories, but this drift somewhat differed between subjects (t=4.7, p<0.001). In Experiment 2 we manipulated the color in the trial proceeding each iteration and found that serial dependence modulated the drift significantly (t=2.1, p<0.05), but some convergence to categories was still apparent. In Experiment 3 we asked subjects to remember two colors on each trial and manipulated the accompanying color on iteration trials. We find that the repulsion away from the accompanying color is much larger in magnitude than both the serial dependence bias and that the apparent drift in the iterated chains is such that converges to color categories is almost entirely obscured by such repulsion (t=4.4, p<0.001). In addition, biases

were modulated by the iterated chain's initial color, suggesting that long-term priors somewhat constrain the interactions within working memory. Overall, these findings suggest that information maintained simultaneously in working memory has a much larger impact than either recent history or long-term memory priors, but long-term priors still impose constraints on these interactions.

Acknowledgements: This research was funded by NSF BCS-1653457 to TFB

Poster Session E > Visual Memory: Working, long-term 2 > Poster E3

Visual working memory and long-term memory attentional control settings: Can we maintain both simultaneously?

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Attentional control settings (ACSs) guide attention in our complex visual environments by determining both which stimuli capture our spatial attention, and which stimuli do not. For example, when searching for a blue shirt, other blue objects will capture attention, but red objects will not. Recent research indicates that humans can maintain a long-term memory (LTM) ACS for 4-30 complex visual objects. Additional recent research indicates that humans can maintain a visual working memory (VWM) ACS for one colour. The purpose of the current experiment was to determine whether it is possible to maintain both an LTM ACS and a VWM ACS simultaneously, such that both kinds of representations are capable of biasing visual spatial attention. Participants memorized and searched for 10 complex visual objects (i.e., the LTM ACS), and on each trial a random colour was presented that participants also memorized and searched for (i.e., the VWM ACS). While searching for the colour and objects, participants completed a modified Posner cueing task designed to measure spatial attentional capture. The results indicate that participants were able to adopt both a VWM ACS and an LTM ACS at the same time, as only cues that matched what participants were currently searching for were able to capture spatial attention. This experiment contributes two important findings: 1) it is possible to maintain both a VWM ACS and an LTM ACS simultaneous, such that both VWM and LTM representations can bias visual spatial attention, and 2) VWM and LTM ACSs operate independently using different resources; if they used the same attentional resources or the same memory resources, it would likely not be possible for both representations to bias visual spatial attentional capture simultaneously.

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Poster Session E > Visual Memory: Working, long-term 2 > Poster E4

Explicit Perceptual Comparisons Modulate Memory Biases Induced by Overlapping Visual Input

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It is well-established that visual working memory (VWM) and perception interact to influence behavior. For example, studies have shown that novel visual input can retroactively distort VWM representations by inducing systematic attraction biases. The size of these biases may be determined automatically by the extent to which features shared between visual input and VWM content overlap with one another. However, it may also be the case that explicitly comparing VWM content to visual input plays a causal role in modulating these observed biases. Here, we tested the hypothesis that explicitly comparing a VWM representation to a visual input causally amplifies memory biases that occur naturally as a result of overlapping visual features. In each trial of two separate experiments, participants first encoded a target visual item (i.e., color or shape) into VWM in anticipation of a continuous report that followed a blank delay interval. On a subset of trials, participants were presented a novel probe item during the blank delay and were instructed to compare it to the target held in VWM. The memory biases observed in this task were then compared to those observed in a separate task where the same participants ignored the probe (Experiment 1) or encoded the probe into

VWM alongside the target (Experiment 2). We found that individuals reported larger attraction biases in the target item following explicit comparisons than when they ignored or remembered the probe. A follow-up analysis revealed that memory biases were amplified when participants judged the probe to be similar—but not dissimilar—to the target item. This pattern persisted even after the distance between the target and probe items in the stimulus space was matched across trials. Taken together, these findings demonstrate that explicit perceptual comparisons causally modulate VWM biases above and beyond the effects determined by shared featural overlap.

Acknowledgements: This work was supported by an NSERC Discovery Grant awarded to KF (RGPIN-2017-06866)

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Saccades disrupt attentional filtering for visual working memory

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To accommodate for our limited visual working memory (VWM) capacity, an attentional filter ensures only goal-consistent information is encoded into VWM. Despite its critical role in dynamic visual behavior, attentional filtering has traditionally been studied in contexts that restrict eye movements. Critically, saccades have been demonstrated to disrupt perception and object-location binding. Does control over the attentional filter persist across saccades, or do saccades disrupt this filter, resulting in the momentary loss of control post-saccade? In E1 (N=15), we established attentional filtering using a no-saccade design. On each trial, participants fixated on a point in one of four locations before seeing a black shape cue indicating that trial's target shape (either a square or circle). Following a variable delay, they briefly viewed an array of four colored shapes—either two circles and two squares (2 targets/2 non-targets), or all four of the target shape—and were told to remember the colors of all the target-matching shapes. One of the target-matching shapes was then probed for report, and participants reported its color by clicking on a continuous color wheel. As predicted, we observed effective filtering: performance was better (i.e., less color report error) when only two items were relevant (SS2) relative to when all four were relevant (SS4). In E2 (N=20), we tested whether this filtering was disrupted by a saccade. On some trials, following the initial target shape cue, participants were prompted to make a saccade, and the stimulus array then appeared after either a short (50ms) or long (400ms) post-saccade delay. We observed significantly disrupted attentional filtering immediately following a saccade (short post-saccadic delay), whereas the filter was successfully reinstated following the long post-saccadic delay. We suggest that saccades disrupt attentional filtering and the filter must be reinstated following a saccade to efficiently filter non-targets from VWM encoding.

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Tracing the emergence of stimulus memorability

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Some visual stimuli are consistently better remembered than others across individuals. This is due to variations in stimulus-intrinsic properties that determine ease of access into visual long-term memory (VLTM). Though memorability has been demonstrated in multiple stimulus domains, it remains an open question where memorability emerges or what cognitive processes give rise to it. As memorability cannot be attributed to low-level visual features, attentional saliency, or voluntary memory control (Bainbridge, 2020), we tested the hypothesis that memorability emerges within visual working memory (VWM). Specifically, do memorable stimuli require fewer resources to be maintained in VWM? If so, more memorable faces should be retained in VWM than forgettable faces. To test this, we had participants perform a standard VWM task with arrays of 3 or 6 face stimuli that were previously classified as "memorable" and "forgettable" (Bainbridge et al., 2013). VWM performance was better in the set size 3 condition compared to set size 6, with an additional benefit for memorable faces, supporting our hypothesis that memorable faces require fewer resources to be maintained in VWM. Interestingly, when memorable faces were presented alongside forgettable ones (e.g., 3 memorable and 3 forgettable faces), memory for the memorable items improved, suggesting that memorable items pull resources away from other items competing for representation. Next, to examine whether memorability can be fully captured within VWM, we had participants perform a VLTM recognition task after completing the VWM task. Here, we found that the memorability effect overrode the array size effect such that memorable faces encoded in 6-face arrays were better recognized than forgettable faces encoded in 3-face arrays. This suggests that not only are memorable stimuli treated differently within VWM, they are also “stickier” than forgettable stimuli, showing less memory decay. Together, our results demonstrate that stimulus memorability emerges over multiple stages of memory.

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Pre-existing semantic associations contribute to memorability of visual changes in a scene

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Ecologically important attributes in a natural scene arise not only from isolated objects, but also from semantic associations among objects in the scene. How these associations affect scene memory is yet fully understood. Here, we investigate this issue by examining how semantic associations of scene elements affect scene memorability using online crowdsourced methods. Study 1 asked mTurk participants to label objects in 1024 scene images and provide subjective ratings of object relatedness, complexity, valence, and arousal of these scenes (~20 participants per image). We calculated semantic associations among scene elements based on Global Vectors of verbal labels. We found that this measure reliably predicted participants’ subjective ratings of scene object relatedness. In Study 2, participants studied a set of 36 images randomly sampled from the 1024 images (~55 participants per image). During a later recognition test, a test image could repeat a study image (“old”) or have an object added or removed from the image (“changed”). Participants reported whether a test image was “old” or “changed." While certain scenes were consistently recognized across participants in “old” trials, we found that scene memorability in “changed” trials varied by type of change and semantic associations among scene elements. Observers often failed to detect a change when an object related to other elements was added to the scene. In contrast, observers more successfully identified a change when an object related to other elements was removed from the scene. Low-level features (e.g., changed area), scene complexity, valence, or arousal could not explain these observations. These results suggest that pre-existing semantic associations impede retrieval by assimilating additional items into a scene but facilitate associative retrieval of missing scene elements. Collectively, our findings indicate that scene memorability is a property of pre-existing associative long-term memory, separable from contributions of lower-level perceptual features.

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The Impact of Multisensory Perception on Incidental Visual Memory

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Studies on visual object memory have historically used unisensory stimuli during encoding and retrieval. However, research has shown that later visual object recognition is improved when the initial encounter is multisensory, such as when a to-be-remembered object is presented as an image along with an identity-congruent sound during encoding. However, these studies have used non-realistic objects, such as line drawings, and explicit instructions to memorize items. The present study uses realistic objects, and introduces a novel task to investigate how auditory information enhances visual encoding by probing incidental memory for visual objects. Participants were presented with visual images of 3D objects (e.g., dog) alongside an object-congruent (e.g., “bark”), object-incongruent (e.g., “ring”), or white noise control sound, and were asked to categorize each as animate or inanimate. In a subsequent, surprise visual recognition task, old images were mixed with new images, and participants were asked to judge whether each object was new, or whether it was old and had initially been presented with a congruent, incongruent, or control sound. Incidental visual memory for previously seen objects was better for objects initially presented with object-congruent auditory information than with incongruent sounds or with a control sound, though there were no significant differences

between the incongruent or control sound conditions. These results extend previous findings of the benefits of multisensory experiences on visual object recognition to longer term incidental visual memories with realistic objects. The results suggest that visual representations are more robust at encoding when accompanied by identity-congruent sounds and that these benefits extend into memory, regardless of intention to encode visual objects into memory. Future investigations will evaluate this effect in increasingly naturalistic situations, with variable delay periods, and with the presence of visual distractor objects during encoding.

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Capacity and Allocation across Sensory and Short-Term Memories

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Human memory consists of Sensory Memory (SM), Short-Term Memory (STM), and Long-Term Memory. SM enables a large capacity but decays rapidly. STM has limited capacity but lasts longer. Previously, it was shown that major bottlenecks for motion processing exist prior to STM (Ogmen et al, 2013. PLoS ONE) and that the contents of SM are allocated exclusively to the current event segment (Tripathy & Ogmen, 2018. Frontiers in Psychology). Here we used mixture modeling to test if the modeling results obtained in Ogmen et al., (2013) also hold for the dataset from Tripathy & Ogmen (2018) in which stimuli contained one to four disks moving in different directions. Each disk changed its direction at the mid-point of its trajectory. The synchronized deviations indicated an event boundary. Observers were instructed to partially or fully report the directions of disks, randomly selected from one of the two event-segments. Experiment 1 varied set-size with cue-delay set to 0 ms. A mixture model consisting of a Gaussian (Memory) and a Uniform (Guessing) distributions found that intake (fraction of target items retained in memory) and precision (1/Standard-Deviation) decreased with increasing set-size. In Experiment 2, set-size was fixed at 3, with a varying cue-delay. Intake dropped gradually and substantially from stimulus encoding to SM and STM, but precision dropped only moderately across memory stages. These results are in agreement with the mixture analysis in Ogmen et al., (2013). We also asked if a mixture model containing two, as opposed to one, Gaussians would capture better the data. Model comparison based on the Akaike Information Criterion favored the two Gaussian model. In summary, we generalized previous findings about memory capacity and bottlenecks using a different data set and propose a mixture model with two Gaussians as a better statistical model than a single Gaussian version.

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Chunking is not all-or-none: hierarchical representations preserve perceptual detail within chunks

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Objects are not stored as unitary representations: memory representations are hierarchically structured in that objects structure memory, but features within objects are mostly independent (Fougnie et al. 2013). Yet prominent chunk learning theories still treat learned chunks as all-or-none bound representations (e.g., in visual memory, “content-free labels”, Huang & Awh, 2018). Here we suggest that as in the case of objects themselves, chunks that combine objects are also hierarchically structured, with preserved information about their contents in addition to the chunk ‘pointer’. We tested this in two ways: In Experiment 1 and 2, we had participants learn new ‘chunks’ using the color-pair paradigm of Brady et al. (2009), in which colors frequently co-occur next to each other in a working memory paradigm (e.g., orange frequently co-occurs with green). However, unlike previous work where the colors were identical on every trial, the colors in these experiments varied in luminance: so although green frequently occurred with orange, the particular green and orange on each trial were unique. We found that (1) learning significantly improved capacity over the experiment; (2) after learning, knowledge about the 2 colors was correlated, showing some binding; and yet (3) participants did not simply encode abstractions (“irish flag colors”), but had preserved knowledge of trial-specific color information as well. In Experiment 3, we relied on existing chunks. Participants were instructed to remember known words (e.g., “GO”) or unknown letter pairs (e.g., “SP”), with letter fonts varying from trial to trial. The presence of pre-existing word chunks helped not only in knowing the letters but also improved knowledge of the fonts -- which contradicts predictions made by

a content-free labels account. Overall we find evidence that memory should be considered hierarchical: Chunks, like objects, serve as cues to access specific information within them, rather than serving as all-or-none abstractions.

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The Depth of Executive Control: Investigating Working Memory, Inhibitory Control and Selective Attention in Multiple Depth Planes

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Previous research demonstrates mixed results regarding the benefit of multiple depth planes on attention. However, no studies have explored how depth information influences executive control broadly. The present work examined the influence of depth on executive control by utilizing three visual tasks; change detection, flanker, and visual search. For the change detection task participants indicated if a cube changed colors with displays of either 2,4,6, or 8 items. In the flanker task participants indicated the direction of a central arrow, with two flanking arrows on either side that were either congruent or incongruent in direction. In the visual search task participants indicated if a target (T) was present amongst distractors (Ls), with either 8,16, or 32 items in the array. For all tasks, depth was manipulated by presenting all the items in the same depth plane or with items separate across multiple depth planes. For the visual search and change detection tasks there was a condition where items were evenly distributed across depth planes. There was an additional condition for the flanker and visual search task where the target was isolated in depth. There were no meaningful depth differences for the flanker task. Benefits for the two other tasks were only seen when the task was challenging (i.e., beyond capacity limits; largest set sizes). Specifically, participants in the change detection task demonstrated a ~7% accuracy benefit for the evenly distributed condition relative to one depth plane. In the visual search task participants were ~620 ms faster and ~12% more accurate when target was isolated in depth, and were still ~6% more accurate in the even distribution condition compared to when all the items where in one depth. Overall, these results suggest that organizing information by depth is useful for selective attention and working memory, but not necessarily for inhibitory control.

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Reconstructing physical representations of block towers in visual working memory

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Recent studies have explored the perception of physical properties (such as mass and stability) in psychology, neuroscience, and AI, and perhaps the most popular stimulus from such studies is the block tower -- since such displays (of stacked rectilinear objects) evoke immediate visual impressions of physical (in)stability. Here we explored a maximally simple question: what properties are represented during natural viewing of such stimuli? Previous work on this question has been limited in two ways. First, such studies typically involve explicit judgments ("Which way will it fall?"), which may prompt encoding strategies that would not otherwise operate automatically. Second, such studies can typically only explore those tower properties that are systematically manipulated as explicit independent variables. Here we attempted to overcome such limitations in an especially direct way: observers viewed a briefly-flashed block tower, and then immediately *reproduced* its structure from memory -- by dragging and dropping an array of blocks (initially presented on the simulated ground plane) using a custom 3D interface. This allowed us to directly measure the success of reproductions in terms of both lower-level image properties (e.g. the blocks' colors/orientations) and higher-level physical properties (e.g. when comparing the stability of the initial towers and their reproductions). Analyses revealed two types of evidence for the visual representation of 'invisible' abstract physical properties. First, the (in)stability of the reproductions (computed, e.g., in terms of the blocks' summed displacements from their original positions, as analyzed in a physics engine with simulated gravity) could not be directly predicted by lower-level image properties (such as the blocks' initial heights or spread). Second, reproductions of unstable towers tended to be more stable, but not vice versa. This work demonstrates how physical representations in visual memory can be revealed, all without ever asking anyone anything about physics.

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Disjunctive strategies for tracking occluded objects in visual working memory in children and adults

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Disjunctive reasoning allows us to infer properties of unobserved objects from currently observed objects, formalized by P or Q, not P, therefore Q. We asked whether children and adults can explicitly use disjunctive reasoning to track occluded objects in an attentionally-demanding visual working memory task. Thirty-six 4-7-year-olds and 6 adults viewed animated arrays of 2-3 virtual “cards” depicting images, which were then occluded by opaque “cups”. In the Face-up block, all images were visible during the brief encoding period. In the Disjunctive block, one of the cards was face down during encoding. During the maintenance period, the occluded cards swapped locations (2-3 times). Two images appeared above one of the cups, and participants were asked to select which image was hidden under that cup (chance=.5). In Disjunctive trials, the location of the face-down card was probed on half of the trials, so participants had to use disjunctive reasoning (P or Q, not P, therefore Q) to respond accurately. Adults were above chance on all trials (ps<.001), and there was no difference in their performance on Face-up vs. Disjunctive trials, suggesting they successfully deployed deductive reasoning. However, children performed significantly worse in the Disjunctive versus the Face-up block (p = .033). While children were above chance on all trials in the Face-up block (ps <.006), children’s performance in the Disjunctive block was only above chance on the easiest trial type (2 objects, 2 swaps, p=.006). Children’s performance in Disjunctive trials was higher when the target had been visible during encoding (p=.033), suggesting they failed to use disjunctive reasoning. Children’s use of the disjunctive strategy increased with age (p=.002). Our results suggest disjunctive reasoning is available as a strategy to improve visual working memory performance in adults, but the development of this ability is extremely protracted.

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Cognitive control is related to spatial memory biases in adults

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When a task-irrelevant object, i.e., a distractor, was presented during a location recall task, pulling attention away from the remembered location, it created a bias in memory such that participants remembered target locations to be closer to the distractor than they actually were (Van der Stigchel et al., 2007). Recent studies in children and adults using similar tasks found that distractors presented during the delay resulted in repulsion from the distractor, such that targets were remembered as further from the distractor (Schutte et al., 2017; Schutte & DeGirolamo, 2020). Beattie et al. (2018) found that inhibitory control (IC) was related to spatial working memory (SWM) biases in children such that greater IC was related to greater repulsion (Beattie et al., 2018). We examined whether IC is related to SWM in adults. Eighty-four adults completed the Spaceship SWM task, a location recall task in which a target was presented at one of two locations that varied by condition. In two-thirds of the trials, distractors were presented near the target. The IC measures included a Cued Go/No-Go (CGNG) task, Simon task, Color Stroop task, and the Barrett Impulsiveness Scale (BIS). Analyses of no-distractor trials found that (a) lower error rates in the CGNG task were related to smaller memory biases away from midline, a common bias in SWM (Spencer & Hund, 2002), suggesting people with greater inhibitory control were less biased; (b) participants who scored lower on the BIS and had higher error rates on the CGNG showed greater memory biases away from midline. This relationship varied by condition. Analyses of no-distractor trials found that individuals with lower error rates in the CGNG task, were repulsed more by the distractor than those with higher errors rates. Overall, these effects demonstrated that IC is related to SWM in adults.

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Visual event boundaries eliminate anchoring effects: A case study in the power of visual perception to influence decision-making

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Visual stimulation is continuous, yet we experience time unfold as a sequence of discrete events. A great deal of work has explored the consequences of such event segmentation on perception and attention, but this work has rarely made contact with higher-level thought. Here we bridge this gap, demonstrating that visual event boundaries can eliminate one of the most notorious (and stubbornly persistent) biases in decision-making. Subjects viewed an immersive 3D animation in which they walked down a long virtual room. During their walk, some subjects passed through a doorway, while for others there was no such event boundary -- equating the paths, speeds, and overall room layouts. At the end of their walk, subjects encountered an item (e.g. a suitcase on the floor) and were asked to estimate its monetary value. The other critical manipulation was especially innocuous, not appearing to be part of the experiment at all. Before the online trial began, subjects reported the two-digit numerical value from a visually distorted 'CAPTCHA' ("to verify that you are human") -- where this task-irrelevant 'anchor' was either low (e.g. 29) or high (e.g. 92). In the no-doorway condition, we observed the well-known anchoring effect: value estimates were higher for subjects who encountered the high CAPTCHA value. Anchoring is especially difficult to resist (even with enhanced motivation, forewarning, and incentives), but remarkably, anchoring was eliminated in the doorway condition. Further experiments replicated this effect in multiple independent samples (and with other objects), showed that it does not depend on explicit memory for the initial anchors, and confirmed that it was due to the event boundary per se (and not to superficial differences such as the visual complexity of the room with and without a dividing wall). This demonstrates how subtle aspects of visual processing can really *matter* for higher-level decision-making.

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Perception and Action: Action and body perception 2

Poster Session E > Perception and Action: Action and body perception 2 > Poster E16

Spatial Heterogeneity of Biological Motion Perception

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Human observers are remarkably sensitive to the biological motion produced by other individuals, an ability that is vital to scene and person recognition as well as navigation. Behavioral and neurophysiological evidence has shown that biological motion occurs at a relatively higher level of visual processing, integrating the inputs from both object form and motion pathways. Recently, researchers have revealed distinct spatial biases in the perception of an object’s location and shape that are retinotopically selective and specific to an individual observer (e.g., Wang, Murai & Whitney, Proc Roy Soc, 2020; Zito et al., Front Behav Neurosci, 2016). Although these kinds of idiosyncratic distortions occur for low-level features, whether this happens at high levels of visual representation—after information is combined across dorsal and ventral streams, for example—remains unclear. Here, we tested whether there are idiosyncratic individual differences in the perception of biological motion at different visual field locations. We presented videos of point-light walkers with discrete heading directions throughout the visual field, and observers discriminated the walker heading direction (left/right). In the analysis, the point of subjective equivalence (PSE) was calculated based on the psychometric curve fitted onto each observer’s responses at each visual field location. The PSEs from each observer were correlated with their own PSEs from a second re-test session and also with other observers’ PSEs. The results revealed stable observer-specific biases across the visual field in perceived heading direction. The between-subject agreement was substantially lower than the within-subject consistency, demonstrating that each individual has their own unique spatial biases in biological motion perception. Our findings suggest that observers have distinct spatial heterogeneities in the representation of integrated form and motion information, and raise the possibility that low-level inhomogeneities in spatial vision may be inherited by subsequent visual processing, potentially biasing high level object and scene recognition.

Poster Session E > Perception and Action: Action and body perception 2 > Poster E17

Aesthetic experience is influenced by causality in biological movements

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What makes some body movements look more elegant than others? We examined whether visual properties in movements contribute to the aesthetic experience from seeing actions. To isolate influences of visual features from those of prior knowledge, we created point-light "creatures" by spatially scrambling locations of a point-light walker's 13 joints. Participants rated how aesthetically pleasing and how lifelike each point-light creature looked in a 2-second video of the creature moving from left to right. In Experiment 1 (N=40), the motion trajectories of the joints were either from an upright walker (thus exhibiting gravitational acceleration), or from an inverted walker (thus defying gravity). In Experiment 2 (N=40), in addition to generating creatures from upright or inverted walkers, the trajectories of the joints were either congruent to the direction of global body displacements, or incongruent (as in the moonwalk). Participants gave higher aesthetic ratings for creatures with upright trajectories than those with inverted trajectories, and for creatures with congruent rather than incongruent movements. Animacy ratings yielded similar differences across conditions. Also, the creatures rated as more alive were seen as more aesthetically pleasing, as evidenced by a positive correlation between animacy and aesthetic ratings. However, after regressing out the influence of animacy, participants still found the creatures that move in a natural causal manner (in accordance with gravity and their body displacements) more aesthetically pleasing. The subtlety of different visual properties between conditions suggests a role of automatic perceptual mechanisms in these preferences of causally-natural movements. Thus, while our conscious minds may enjoy watching the magical moonwalk, our automatic minds, with a taste for causality, may curtail the impression of its visual beauty.

Acknowledgements: National Science Foundation (NSF BCS-1655300) to HL.

Poster Session E > Perception and Action: Action and body perception 2 > Poster E18

Shared and distinct neural representations of human-agent actions and inanimate events

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Action recognition relies on a network of prefrontal, parietal and middle temporal brain regions. A hierarchy of action representation in these regions is observed from specific perceptual and kinematic features such as movements of body parts or modality-specific sensory representations to more stimulus-general, conceptual aspects. However, the functional profiles of these regions remain unclear. Specifically, it is typically assumed that the "action recognition system" refers to a network of regions that supports recognizing actions of humans (e.g., a person jumping over a box). Yet, inanimate entities can also be involved in motion events that are structurally similar to human-agent actions (e.g., a ball bouncing over a box). Here, we used fMRI-based MVPA to test which components of the action recognition system encode action representations that are specific to goal-directed actions of human agents or more general representations that also define structurally similar non-agentive motion events. During fMRI, participants observed structurally similar human-agent actions and inanimate events. Cross decoding revealed that large parts of prefrontal, parietal and middle temporal cortices carry similar representational profiles in encoding meaningfully different human-agent actions or non-agentive motion events. Furthermore, a subregion in right superior temporal sulcus could better distinguish human-agent actions compared to non-agentive actions. These findings imply that action representations that are encoded in these frontoparietal and middle temporal regions cannot be limited to sensorimotor features specific to human-agent actions. However, the action recognition system also contains components that are distinctly associated with human-agent motion processing.

Poster Session E > Perception and Action: Action and body perception 2 > Poster E19

A data-driven investigation of human action representations

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Daily life requires us to recognize many actions performed by other people. How do we represent such a large number of possible actions in order to efficiently identify them? Prior work suggests that human action representations are organized along a small number of simple dimensions, such as sociality (person-relatedness) and transitivity (object-relatedness). However, most studies have relied on small-scale, controlled stimulus sets to test these dimensions. Here, we curated a naturalistic set of 152 videos sampling a wide range of everyday actions. In an online experiment, 300 participants arranged the videos according to their similarity, broadly defined so as to avoid constraining behavior. We constructed a representational space based on the distances between stimuli using inverse multi-dimensional scaling (Kriegeskorte & Mur, 2012). We then used a data-driven approach, sparse non-negative matrix factorization (NMF; Hoyer, 2004), to investigate the dimensions underlying this behavioral similarity space. By applying sparsity and positivity constraints, NMF can recover continuous interpretable dimensions while also allowing categorical structure to emerge. Nine dimensions were sufficient to reconstruct behavioral responses in held-out data. A separate set of participants labeled the most reliable dimensions as: family; manual labor and chores; communication and office work; locomotion and nature; food and social life; and conflict. These dimensions generalized across different scene settings and action categories within our dataset and were also validated in a separate odd-one-out experiment. While the dimensions were interpretable, none of them mapped onto any previously identified feature space (e.g., sociality or transitivity), highlighting the usefulness of our data-driven approach in generating new hypotheses. Our results suggest that broad distinctions between work, leisure and home life, rather than binary features, organize human action representations. Furthermore, these representations contain more fine-grained information about social relationships and their valence than previously suggested.

Acknowledgements: This material is based upon work supported by the Center for Brains, Minds and Machines (CBMM), funded by NSF STC award CCF-1231216.

Perceptual Organization 2

Poster Session E > Perceptual Organization 2 > Poster E41

Modeling visual estimation of the centers of symmetric distributions

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Estimating the summary statistics of arrays of items is a key visual operation (see Jacoby, Kamke & Mattingley, JEP:HPP, 2013). In previous work (Ota et al., VSS, 2020), we presented human observers with 9-point samples (points on a computer screen) drawn from three families of symmetric population density functions (Gaussian, Laplace, and Uniform) and asked them to estimate the center (axis of symmetry) of the population given only the sample and knowledge of distributional family from which it had been drawn. We tested whether observers estimate the center differently if they know that the points are drawn from, for example, a Uniform. We found that the visual system treated samples from three different populations differently but that no obvious normative criterion (e.g., minimum variance) captured what observers had done. Here we describe a process model intended to capture human performance for all three distributions. We propose that the center estimate is a weighted linear combination of the nine sample points but that the weights assigned to each point depend on two factors. The first is a global agreement of each sample point with the others (a measure based on likelihood) and the second depends upon the clusters to which the point belongs. Intuitively, points within a cluster are assigned more weight in estimation. These two steps can be interpreted as two opposite constraints the visual system has to optimize, the integration of the points (likelihood) and their segmentation (clusters). We show that this two-step model can account for observed quantitative differences in performance with the three distributions. These results illustrate that our visual system is sensitive to the distributional family when estimating the summary statistics of a sample drawn from the family, and that the center estimates of symmetric distributions can be described by a single model of perceptual organization.

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The figural shape of 3D concave regions activates temporopolar cortex

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BACKGROUND: According to theories of figure-ground segmentation, observers ought not to perceive figural shape from 3D concave regions. While concave regions may have a global bounding contour, the figure-ground and part parsing cues provided by their minima of curvature always indicate that the bounded region should not form a coherent figure. Nonetheless, 3D concavities are perceived to have figural shapes, although they do not cue attention in an object-like way (Cate & Behrmann, 2010) and activate object-selective cortex less than convex regions (Haushofer et al., 2008), similar to 2D aperture holes (Albrecht et al., 2008; Vinberg & Grill-Spector, 2008). We propose that temporopolar cortex implicated in illusory depth reversals in the hollow-face illusion may be critical for perceiving figural shape from 3D concavities. METHODS: 19 healthy participants performed a fixation cue discrimination task during block design fmri. Three different blocks displayed truncated rectangular prisms oriented as concave with respect to the frontoparallel plane, which appeared at 3 different fixation disparities (including both crossed and uncrossed); three blocks displayed convex prisms. Four blocks displayed flat frontoparallel stereograms using the same fixation disparities as the concave and convex blocks, which served as controls for the effects of absolute disparity. Stereograms were projected into the scanner using a PROPixx DLP projector with a circular polarizing filter running at 120 Hz (60 Hz/eye). Activation in the superior temporal pole was analyzed with small volume correction, and otherwise activations were thresholded using family-wise error correction in SPM8. RESULTS: Contrasting concave versus convex 3D stereograms showed activation in the left hemisphere superior temporal pole (BA 38), while convex versus concave activated lateral occipital cortex bilaterally. CONCLUSION: The same process that produces illusory depth in the hollow-face illusion may enable perception of figural shape from concave regions.

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Relative surface area biases figure-ground reversibility in abstract images

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Gestalt psychologists emphasized the importance of figure-ground assignment in the process of perceptual organization. A border separating two regions “belongs” to the region perceived as figure. This region is seen as an occluder covering the ground region. In some configurations, such as Rubin’s (1929) faces-vase, figure-ground assignment is ambiguous and can be reversed. Previous research has demonstrated color spreading illusions can bias figure-ground reversibility in ambiguous stimuli such as the faces-vase (Hale, 2018) and in stimuli with no semantic content (Hale & McDunn, 2019). In the current study, we manipulated relative surface area and luminance to determine if these factors impact figure-ground organization under certain stimulus conditions. Stimuli were centrally located squares on a dark background. Each stimulus consisted of a light gray region and white region separated by one of six wavy contours, resulting in left and right regions. Participants viewed these images on a screen and reported whether the left or right region of each stimulus appeared to be the foreground. The wavy contour was either centrally located, shifted left, or shifted right, resulting in a perceived size change between stimuli (i.e., matched size, larger right, or larger left). Light gray and white alternated between left and right. Trials were presented in a random order in this within-subjects design. All six wavy contours, when centrally located, were statistically reversible implying no figural bias for left versus right. A 2 (Luminance) x 2 (Surface Area) repeated-measures factorial ANOVA found no main effect of luminance and no interaction between luminance and surface area. However, a main effect of surface area was found, suggesting larger regions were biased toward figure and smaller regions biased toward ground. Based on these findings, we plan to re-introduce color spreading illusions to investigate the interaction of these factors on figure-ground organization.

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Do Semantic Expectations Influence Object Detection? A Stringent test using figure assignment responses

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We investigated whether semantic expectations initiated by words influence object detection and, if so, whether effects are mediated by feedback from high to low levels or by high level activation involved in object detection. Participants viewed briefly presented displays divided into two equal-area regions by a central border; a familiar object (upright/inverted) was suggested on one side. Displays were masked to shorten reentrant processes. Participants reported which side they perceived as figure. Before each display, experimental group participants viewed a word denoting either the familiar object at a basic level (BL) or an unrelated (Unr) object in a different category. Control group participants viewed test displays only. We assessed object detection via speed/accuracy of reports that the object lay on the familiar configuration side. Prime effects were indexed by differences in these DVs between experimental and control groups. If semantic activation influences object detection via feedback to lower feature levels, BL primes should increase, and Unr primes should decrease, object detection accuracy. In Study 1 (90-ms displays) BL primes increased accuracy and reduced RTs for upright displays only, ps<0.04. No effects of Unr primes were observed. Hence, feedback to lower levels does not mediate semantic expectation effects. Results suggest the BL prime boosts activity in the neural population representing the familiar object, a population response that takes longer for inverted than upright objects. Study 2 (100-ms displays) allowed more time for display-generated semantic activation to build and to potentially conflict with activity initiated by the Unr prime. Following BL primes, accuracy increased for both orientations, ps< 0.01. Following Unr primes, detection RTs were longer for upright displays, p< 0.03, yet accuracy was unaffected, suggesting that RTs were longer because semantic conflict had to be resolved before object detection. These results implicate high level semantic activation in object detection.

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Poster Session E > Perceptual Organization 2 > Poster E45

On the hole, interpretations of Venn diagrams are influenced by perceptual organization

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Research on colormaps demonstrated that expectations of how visual features map onto concepts are governed by two biases: dark-is-more (darker colors map to larger quantities) and opaque-is-more (more opaque regions map to larger quantities) (Schloss et al., 2019). We investigated whether these biases generalize to another system: Venn diagrams. Venn diagrams represent properties with overlapping regions and express logical relationships between those properties by using lightness level to encode “non-existence.” Given that “non-existence” is the extreme opposite of “more,” the dark-is-more bias implies people will infer that lighter regions signify non-existence. The opaque-is-more bias implies people will infer the least opaque region signifies non-existence. At its extreme, the least opaque region can appear as transparent or as a hole. Holes in surfaces arise from non-existing material, so we predicted people would analogously infer that regions appearing as holes map to non-existence (hole hypothesis). We tested these predictions by presenting participants with a series of logical statements, each paired with two Venn diagrams. Their task was to indicate which diagram best matched the statement. We determined the proportion of diagram choices consistent with inferring that light or dark regions signified non-existence. We varied diagram and background color so as to dissociate effects of dark-is-more and opaque-is-more biases and test the hole hypothesis. Experiment 1 provided evidence especially for the opaque-is-more bias; responses suggested participants inferred the least opaque region mapped to non-existence (p<.001). Experiment 2 discounted an alternative lightness-contrast account; background lightness only mattered when color relations were consistent with opacity variation (p<.001). Experiment 3 supported the hole hypothesis; background

lightness had a larger effect when there was perceptual evidence for a hole compared to when there was merely perceptual evidence for opacity variation (p=.001). Thus, previously observed biases generalize across different systems, and perceptual organization influences interpretations of Venn diagrams.

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Visual Salience and Grouping Cues Guide Relation Perception in Visual Data Displays

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Reading a visualization is like reading a paragraph. Each sentence is a comparison: the left ones are bigger than the right ones, this difference is smaller than that, the red lines are increasing but the yellow lines are decreasing. What determines which comparisons are made first? People often group objects by ‘spatial’ (e.g., proximity) and ‘featural' (e.g., colors, size) cues. When grouping cues compete, spatial cues tend to beat featural cues (Brooks, 2015; Wagemans, Johan, et al., 2012), as they appear to be processed in parallel across a display (Franconeri, Bemis, & Alvarez, 2009), in contrast to featural cues that are argued to be grouped by only one value (a single color, shape, or size) at a time (Huang & Pashler, 2002; Yu, Xiao, Bemis, & Franconeri, 2019). Using bar charts as a case study, we explored how spatial, size, and color similarities impact which relations people tend to extract from visualized data. We showed participants various 2x2 bar charts depicting different main effects and interactions, asked them to generate sentence comparisons about the bar values, and analyzed how often participants compared bars that had similar sizes (bar height), similar colors, or were spatially proximate. We found that participants were approximately 31% more likely to generate sentences comparing spatially proximate bars than spatially separated ones. This tendency was doubled when the spatially proximate bars had similar sizes and halved when they didn’t. Interestingly, participants rarely grouped and compared bars by color, such that varying color mapping in bar charts had a negligible impact on what comparisons a viewer would make.

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The Bar-Tip Limit Error: a Common, Qualitative Misinterpretation of Bar Graphs of Means Revealed by the DDoG Method

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Though controversial, bar graphs of means (BGoM) remain popular for their presumed accessibility to non-experts. This presumption remains, however, largely untested. In this study we present six principles for optimization of graph comprehension assessment measures, utilize these principles to create the Draw Datapoints on Graph (DDoG) method, and deploy the new method to document a common, severe, qualitative error in BGoM interpretation. We label this identified behavior the Bar-Tip Limit Error (BTLE), because adherents represent BGoM data distributions as limited by, rather than distributed across, the bar-tip. BTLE is observed in ~20% of participants: a rate that is consistent across educational levels, ages, and genders. It persists across those who correctly supply the mean value from a BGoM; those who accurately define the word mean; and, critically, despite explicit and repeated instructions that the bars represent means. Those who exhibit the BTLE once tend to repeat it across bar graphs that vary widely in form and content, suggesting that the error results from a fundamental misunderstanding of BGoM. In a survey of bar graphs from several educational and general sources, we found that the majority showed counts or percentages, as opposed to mean values. We therefore hypothesize that the BTLE reflects an acquired, and expertise-associated, conflation of two bar graph types whereby BGoM are assumed to operate like bar graphs of counts (BGoC). The existence of a severe and prevalent misunderstanding of BGoM suggests the need for evidence-based interventions potentially including point-of-contact annotations of BGoM, replacement with alternative graph types, and changes in curricula and statistical software to emphasize distributional understanding.

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Correlation perception in scatterplots is invariant to dot size

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To determine the extent to which the perception of Pearson correlation r in a scatterplot depends on its appearance, we examined the effect of dot size on discrimination and magnitude estimation. Scatterplots were formed of 48 solid black dots on a white background, with axes 6.5 cm by 6.5 cm, and distribution standard deviations 1.3 cm. Observers (N=18) were tested via a within-observer design involving five conditions: dot diameters of 1 mm, 3 mm, 5 mm, 8 mm, and a mix of these sizes. Viewing distance was 67 cm. The methodology was that of Rensink and Baldridge (2010). In the discrimination task, observers were asked to select the plot with the higher perceived correlation; the just noticeable difference (JND) was measured at three base correlations (0.3, 0.6, 0.9). In the magnitude estimation task, observers adjusted a test plot until its perceived correlation was midway between those of two reference plots. The discrimination task was sandwiched between two sets of estimation tasks. All conditions were counterbalanced by base correlations and dot size, using a Latin square. The resulting JNDs were slightly higher than those reported by Rensink and Baldridge (2010) and Rensink (2017), but were still strongly linear functions of correlation ($R^2=0.97$); the Fechner assumption of equal perceived difference for each JND was also supported. Importantly, neither discrimination nor estimation were significantly affected by dot size. This further supports the proposal (Rensink, 2017) that perceived correlation in scatterplots is based not on the physical appearance of the scatterplot, but on a more abstract quantity, such as the shape of the probability density function derived from the locations of the dots in the image.

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Physical event representations: Observers spontaneously impose discrete temporal structure in intuitive physical scene understanding

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Most computational and psychophysical work in intuitive physics treats time as continuous. Yet, from infant cognition to language, discrete interactions between objects and external forces dictate how we think about them: objects collide, fall, topple; liquids splash, slosh, pour; cloths flap, billow, drape. Do we also see physical scenes as structured over time during online perception? We propose that the visual system uses a set of intuitive physical rules to segment continuous experience into a sequence of physical events: causal contexts that are sufficient to explain motion patterns of objects within that event. In Experiment 1, we showed participants videos of three-dimensional physical scenes with objects rolling, sliding, colliding, toppling, falling, and entering or exiting containers and occluders. Participants described these physical scenes containing individual events. Using natural language processing, we verified that videos could be distinguished by the event types that compose them. In Experiment 2, we investigated whether we represent temporal boundaries between physical events in perception. Participants viewed combinations of events (e.g., a ball collides with another ball, which then goes behind an occluder) with or without a temporal probe (a 125ms interval in which the video slows down) and pressed a key immediately upon perceiving a probe. Probes occurring at boundaries between events, compared to probes at non-boundaries, were significantly less likely to be detected. Participants were also significantly less confident in their judgments of these probes, and even when these probes were correctly detected, reaction time was slower. Importantly, absolute pixel change was not different between boundary vs. non-boundary probes. These results suggest that the mind spontaneously imposes discrete temporal structure over continuously unfolding state-space of objects and forces, providing support for physical event representations as building blocks of the mind and a tractable “model organism” for studying event cognition in neurological and modelling studies.

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Contextual modulations in high-level vision are partly accounted for by low-level mechanisms

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Context modulates the encoding of low-level (e.g. gratings) and high-level (e.g. human face features) visual stimuli. In both cases, the magnitude of contextual influence depends on the strength of the target signal (e.g., contrast, facial feature saliency), and there is variability in susceptibility to contextual effects across individuals. It is currently unclear whether high-level contextual effects are mainly caused by category-specific mechanisms, or are also accounted for by lower levels of the visual processing hierarchy. In order to clarify this, we evaluated whether an individual's susceptibility to contextual modulations correlates across low- and high-level vision. In our low-level task, we measured individuals' contrast detection performance of a horizontally oriented Gabor patch (ie, target signal) embedded within a parallel (same) or orthogonally (different) oriented, bigger Gabor (ie, context; similar to Mannion et al., 2017). The same individuals were tested in a high-level task using a delayed matching paradigm in which they judged whether the eye region (target signal) was strictly identical or different across same or different faces (context). Target signal strength (Gabor patch contrast) in the low-level task was manipulated using an adaptive staircase, whereas in the high-level task, it (eye dissimilarity) was manipulated using fixed morphing steps. Contrast detection performance in low-level task, and the proportion of "different" responses in high-level task followed a sigmoidal function as the target signal strength increased in all conditions. Slope and intercept values of these functions were taken and subtracted across context conditions (same-different) within each task, quantifying an individual's susceptibility to contextual effects. We observed a trend towards a moderate negative relationship between an individual's susceptibility to contextual modulations in low- and high-level tasks. These results suggest that high-level contextual modulations are in part accounted for by contextual mechanisms involved in low-level vision.

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Perceptual Organization: Contours and shape

Poster Session E > Perceptual Organization: Contours and shape > Poster E51

Cortical magnification analysis of shape adaptation reveals early curvature coding mechanisms

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Background. Sustained stimulation of the retina with a circular stimulus produces the impression of a polygon (Khuu et al 2002, Ito 2012). What could explain this surprising phenomenon? A low-level account posits an opponency between localized curvature-tuned neurons in early visual cortex, while a high-level account assumes an opponency between neurons in higher visual areas coding whole shapes. To test these competing accounts, we measure how the illusion varies with the size and eccentricity of the stimulus. While a high-level account predicts invariance to size and position, a low-level account predicts that the order of the perceived polygon will increase with the size and decrease with the eccentricity of the stimulus, due to cortical magnification. Method. We employed the method of Sakurai (2014) to rapidly induce the circle-polygon illusion. The stimulus was a static dark outline circle augmented with a 2 Hz pulsed luminance gradient around the inner border. Both the radius and eccentricity of the stimulus were varied in a crossed design over 1-8 deg. Observers indicated their percept by selecting from a palette of shapes that included a circle and polygons of orders 3-10, and also reported the strength of the polygon percept on a 0-10 scale. Results. As previously reported, the strength of the percept increased with eccentricity. Importantly, the mean order of the perceived polygon systematically increased with stimulus size and decreased with eccentricity. To relate this more clearly to the underlying neural substrate, we computed the circumference of each stimulus in both retinal and cortical coordinates, taking cortical magnification into account. Linear regression analysis reveals that the cortical size of the stimulus is a significantly better predictor of perceived polygon order. Implications. These results suggest that the circle-polygon illusion arises from and reveals the architecture of an early visual opponent mechanism for curvature coding.

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Early Visual Cortex Reflects Object-Based Perceptual Warping

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Perceptual organization of incoming visual information gives rise to distinct objects. It has previously been demonstrated that the presence of an object can warp the spatial region within object boundaries. This effect, known as Object-Based Warping (OBW), occurs when two items placed within the contours of an object are perceived to be further apart relative to two equidistant items not enclosed within an object (Vickery & Chun, 2010). Here, we used fMRI to investigate the neural representation of object-based warping. To measure the strength of the behavioral effect, participants adjusted the perceived distance between two letters so as to match two reference letters (either enclosed within an object or not). A subset of participants (n=7) who exhibited a behavioral effect of substantial magnitude also completed an fMRI experiment consisting of a letter discrimination task. The task included 3 conditions: (1) two letters enclosed within an object, (2) two letters without an object at the same spatial distances as in condition 1, and (3) two letters without an object at the “warped” distances (calculated from behavioral data). We separately localized retinotopic regions corresponding to the real and warped positions at which the letters were presented. Using BOLD activation extracted from these regions, an MVPA classifier was trained on the two no-object conditions (conditions 2 & 3) and tested on the object-present condition (condition 1). Activation corresponding to letters presented within an object (condition 1) were classified significantly above chance as matching the warped locations (condition 3) in both V1 & V2d; constituting evidence of OBW only in these regions. This warping effect in early visual cortex is likely driven by feedback from higher-level regions and suggests a fundamental change to visual perception caused by the presence of a simple object.

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Representational similarity analysis of 7T fMRI data suggests disorganized contour processing in psychosis

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Contour integration, the process of joining spatially separated elements into a single unified edge, has consistently been found to be impaired in schizophrenia. Whether contour integration is impaired among patients with psychosis more broadly remains unclear. We examined a transdiagnostic sample of 34 participants with psychosis, 24 first degree biological relatives without psychosis, and 24 healthy controls with no family history as a part of the Psychosis Human Connectome Project. We used 7 tesla functional MRI (fMRI) to measure responses across visual regions-of-interest (ROIs), including primary visual cortex (V1), lateral geniculate nucleus (LGN), and lateral occipital complex (LOC), during a contour integration task. Across all participants, univariate V1 fMRI responses were lower for aligned versus scrambled contours, consistent with previous studies of predictive coding. Participants with psychosis had stronger fMRI responses in LOC for contours presented within a field of background elements, also consistent with prior studies. We performed a representational similarity analysis (Kriegeskorte, 2008) to quantify patterns of responses across voxels within ROIs in individual subjects. Across V1 and LOC, similarity was highest for task conditions with the same configuration of background elements, indicating that the presence or absence of background elements had a strong effect on the fMRI response patterns in these regions. Additionally, in both V1 and LOC, highest similarity was seen between task conditions with a discernible contour. Patients with psychosis showed lower similarity in V1 between same-background conditions, as compared to healthy controls, consistent with disorganized contour processing among patients. Our results are consistent with prior findings of impaired contour integration in schizophrenia, and suggest abnormalities in the multivariate pattern of neural responses in early visual cortex among patients with psychosis.

Acknowledgements: U01 MH108150, K01 MH120278, P41 EB015894, P30 NS076408, UL1 TR002494

Independent Mechanisms for Processing Local Contour Features and Global Shape

View Poster | Visit me in Gather.Town Manatee Room on Monday 3:30 pm - 5:30 pm EDT

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We perceive and represent the overall shape of an evergreen tree despite many deviations and irregularities in branches and needles along its boundaries. This sort of phenomenon is hard to understand if all contour information is combined into a shape percept. We propose a new hypothesis about separate systems for processing local contour information and global information about overall shape. These systems are independent and process information differently. Whereas the global system encodes low frequency contour variations accurately, the local system encodes only a small set of summary statistics to describe typical features of high frequency variations along a contour. In Experiment 1, we tested this hypothesis by sequentially showing two shapes that could differ in local features, global features, or both. Participants showed low sensitivity to changes in local contour features and a lack of additivity for shapes that differed in both local and global features compared to shapes that differed globally. In Experiment 2, we controlled for the amount of physical dissimilarity between local and global shape changes. Sensitivity remained higher for global features with physical similarity equated. In Experiment 3, we compared participants' sensitivity to new sets of contour features with matched statistical properties with new features that differed in frequency and amplitude. Sensitivity to change was higher when statistical properties changed than when new features were generated from the same statistical distribution. We directly tested our hypothesis of the independence of local and global properties in Experiment 4 using a visual search task. Although local and global shape differences each produced pop-out out on their own, search when they were integrated together required focal attention. Taken together, these findings support the notion that separate mechanisms process local and global contour information and that the kinds of information these mechanisms encode are fundamentally different.

Poster Session E > Perceptual Organization: Contours and shape > Poster E55

Aging and the perception of texture-defined form

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A single experiment required 28 younger and older adults to discriminate global shape as defined by differences in texture. The stimulus patterns were 3-point micropattern textures (cf, Caelli & Julesz, 1978). On any given trial, a texture-defined shape (either a vertically- or horizontally-oriented rectangle) was presented; the observers' task was to discriminate between the two rectangles. The task difficulty was manipulated by varying the deviation from colinearity of each of the individual 3-point texture elements between figure and background (the larger the difference in deviation between figure and ground, the higher the discrimination performance). A substantial effect of age was found: in order to perceive the target rectangle and discriminate its shape with a d' value of 1.5, the older observers needed differences from colinearity that were 54.4 percent larger than those required for younger adults. The results indicate that while older adults can visually perceive global shape defined only by differences in texture, their abilities are nevertheless significantly compromised.

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Boundary segmentation from luminance and texture cues: Underlying mechanisms

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Segmenting the visual scene into distinct surfaces is one of the most basic aspects of visual perception. In natural scenes, adjacent surfaces often differ in mean luminance, which provides an important boundary segmentation cue. However, mean luminance differences between two surfaces may occur without any sharp change in albedo at their boundary, but instead arise from differences in the proportion of small light and dark texture elements within each surface. Here we investigate the performance of human observers segmenting such “luminance texture boundaries”.

Luminance texture boundaries were synthesized by placing different proportions of white and black Gaussian micropatterns on opposite sides of a boundary whose orientation was left-oblique (-45 deg. w.r.t. vertical) or right-oblique (+45 deg.), and observers identified the boundary orientation in a 2AFC psychophysical task. We demonstrate that a model based on a simple luminance difference computation cannot explain observers' boundary segmentation performance. However, extending this one-stage model by adding contrast normalization successfully accounts for these data. By performing further experiments in which observers segment luminance texture boundaries while ignoring super-imposed luminance step boundaries, we demonstrate that the one-stage model, even with contrast normalization, cannot explain psychophysical performance. However a Filter-Rectify-Filter (FRF) model, positing two cascaded stages of filtering, fits this data very well, and furthermore can account for observers' ability to segment luminance texture boundary stimuli, both in the presence as well as absence of interfering (masking) luminance step boundaries. We propose that such multi-stage luminance difference computations may be useful for boundary segmentation in natural scenes, where shadows often give rise to luminance step edges which do not correspond to surface boundaries.

Acknowledgements: Supported by Canadian NSERC Grants OPG0001978 to C.L.B

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Spatial and chromatic properties of numerosity estimation in context

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Humans can rapidly and accurately estimate small number of objects without relying on counting, a process known as subitizing. Objects in natural scenes rarely occur in isolation but are surrounded by other objects or embedded in textured surfaces. Here we investigate how spatial organisation of context elements affects numerosity estimation and whether numerosity mechanisms are selective to elements' colour, luminance polarity and orientation. Stimuli consisted of a small number (3 to 6) of target elements (Gaussian blobs) presented either in isolation or embedded in context elements. The target and context elements were dissociated by luminance polarity. We varied spatial configuration of (i) target elements by placing the elements either mirror-symmetric, on the vertices of simple geometric shapes or random, and (ii) context elements, by organising the surrounding elements either in a grid, mirror-symmetric, translation-symmetric or random. To examine the selectivity to target-elements' features e.g., colour, luminance polarity, orientation (Gabors), we compared target-only conditions in which all elements were either the same or different in one of these particular features. We measured accuracy and reaction times (RTs) while participants performed a numerosity estimation task. We found (a) lower accuracy and slower RTs for all target-types when presented in context than in isolation, and for larger (5,6) than smaller (3,4) target numerosity; (b) significantly better performance with the grid compared to mirror-symmetric, translation and random contexts, except for 6 target-elements condition where the grid context yielded the lowest accuracy; (c) comparable performance in the same and different feature conditions for colour, luminance polarity and orientation in the absence of context; (d) better performance with shape than symmetric and random positioned target-elements. We conclude that numerosity mechanisms are not selective to colour, luminance polarity and orientation, and that symmetric, translation and random organisations of context elements inhibit target-numerosity encoding stronger than regular/grid context.

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The Channel Between Perception and Cognition Is Perfect: The JND Does Not Exist

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In magnitude discrimination tasks (e.g., which ensemble is more numerous?), differences that are more difficult than the ratio specified as the JND (e.g., 8 vs. 9 dots) are sometimes understood to be completely imperceptible. The Just Noticeable Difference (JND) is often defined as the minimum amount of difference between two values required to be perceivable. Importantly, if analog magnitudes, the most common type of representation in visual perception and cognition, are represented as a series of gaussian tuning curves with linearly increasing variability, as is also often assumed, then there should be no ratio other than 1 at which perception transitions qualitatively from "success" to "chance" performance: More boldly, there should be no JND. To test whether subjects can perform above chance at

ratios far more difficult than a typical JND, we asked online subjects (N = 207) to complete a series of trials judging which of two ensembles has more dots, where the trials contained increasingly difficult ratios: between 20 vs. 30 dots (ratio 1.5) up to 50 vs. 51 dots (ratio 1.02). We found that subjects were able to successfully discriminate all tested ratios above chance, all ts > 4.6, all ps < .001. That is, we found that people are sensitive to differences even at a ratio of 1.02, which is far below the point typically thought of as a JND. We anticipate that many scientists may already be familiar with these points (e.g., a JND at 75% correct is not a unique datapoint and subjects will be above chance both above and below this JND). But many (perhaps the majority) of scientists have misunderstood the JND to mark a critical boundary below which differences are imperceptible. Our work shows that, given enough trials, any difference in magnitude, no matter how small, will indeed be perceivable.

Motion Perception: Models and neural mechanisms

Poster Session E > Motion Perception: Models and neural mechanisms > Poster E59

Additive contrast strengths model of perceived motion direction of equal-spatial-frequency plaids

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Three-motion-system theory proposes that, at the early stage, dynamic scenes are analyzed independently by three different motion systems; the first-order system extracts motion signals defined by luminance, the second-order system extracts motion defined by contrast modulations, the third-order system extracts motion defined by salience (Lu & Sperling, 1995 Vision Research, 35, 2697-2722). So far, most of the work regarding the three-motion-system theory has focused on one-dimensional, drifting sine-wave or square-wave gratings whose motion is defined only in the direction perpendicular to the grating orientation. Here, we extend the application of the three-motion-system theory to two-dimensional plaid stimuli that are composed of two equal-spatial-frequency sine-wave gratings. We show that a 20-30Hz plaid, which only activates first-order system, is perceived to move coherently in between the directions of the plaid's two sine-wave components. Moreover, the perceived direction is perfectly predicted by a combinational rule that assigns weights to each sine-wave component according to a power function of their contrasts. The power is between 1.5 and 2.5 for different subjects (Sperling et al, 2020 Psychological Review, 127:305-326). At 1Hz which preferentially activates the third-order system, a plaid composed of two equal-contrast, equal-spatial-frequency sine waves is perceived to move coherently in the pattern direction (the motion direction of maxima and minima at intersections of the sine-wave components). At intermediate temporal frequencies (3Hz), a plaid is perceived to move, also coherently, in between the pure first- and the pure third-order system's predicted directions. The perceived direction for the intermediate-temporal-frequency plaids reflects the additive combination of the first- and third-order system's outputs. We demonstrate that the strength of the third-order system varies with contrast. The subjects' perceived directions for 3Hz plaids reveal that the strength of the third-order system also is a power function of contrast with exponents between 2.9 and 4 for different subjects.

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Neural coding for the illusion of direction repulsion of transparently moving stimuli

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Humans perceive the angle separation (AS) between two overlapping random-dot stimuli that move transparently in different directions to be wider than it actually is when the veridical AS is less than 90°. The neural basis for this illusion of direction repulsion remains unclear. We recorded from neurons in middle-temporal (MT) cortex of two fixating macaques. Visual stimuli were overlapping random-dot patches (diameter 7.5°) moving in two different directions. The AS was 30°, 45°, 60°, 90°, or 135°. We varied the vector-averaged direction of the bi-directional stimuli to characterize a neuron's response tuning curve, and also measured each neuron's direction tuning to a single patch. Visual stimuli had

eccentricities from 1.5° to 29° (median=6.3°). We fitted tuning curves to bi-directional stimuli as a weighted sum of the responses to the two component directions, plus a multiplicative term between component responses. In the model fit, we allowed the "component directions" to deviate from the veridical component directions, with either a wider or narrower AS. The best-fit component directions averaged across neurons (n≥96) had mean AS of 54°, 69°, 94°, and 133° for veridical AS of 45°, 60°, 90°, and 135°, respectively. Consistent with human perception, we found a significant effect of direction repulsion at AS of 45° and 60° ($p<0.0001$), but not at 90° and 135°. Furthermore, the ratio between the overestimated AS and AS (i.e. ΔAS/AS) decreased from 0.2 to -0.015 as the AS increased from 45° to 135°. However, in a smaller neuron sample (N=38), we did not find direction repulsion at AS of 30°, which may be due to stimulus eccentricities and the small AS. In conclusion, we found that within a range of AS, MT neurons encode transparently moving stimuli as if they have a wider AS, which would allow a decoder to read out repelled motion directions.

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Adaptive Trade-off between Sensitivity and Spatial Resolution and its Implications for Motion Discrimination and Segregation

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The success of species depends critically on their ability to process and extract sensory information under a wide range of ecological conditions. For example, on a normal day, the luminance impinging on the retina varies within a dynamic range of 220 dB. Stimulus contrast can also vary drastically across the visual field due to shading, camouflage, etc. Given the limited dynamic range of human neurons, the brain deploys both structural and functional mechanisms that work in tandem to cope with these changes. Here, using a few canonical neural computations, such as shunting (Hodgkin-Huxley) dynamics, center-surround receptive-field (RF) organization, and nonlinearities, we show how a two-layer biologically-plausible neural architecture can model these mechanisms. The first layer accomplishes contrast-normalization as an emergent property of RF organization in shunting dynamics (Grossberg, 1988). The second layer implements contrast-dependent spatial processing, wherein distinct nonlinearities for center and surround control the dominance of summation and suppression according to contrast. Summation dominates at low contrast to improve weak signals whereas suppression dominates at high contrast to improve spatial resolution. We compared the predictions of the model with data (Tadin et al., 2003) showing that indeed increasing the spatial size of a low-contrast stimulus improves the discrimination of motion-direction whereas the opposite occurs with a high-contrast stimulus. Similarly, via a small modification, our model could account quantitatively ($\chi^2(10)=1.07, p>0.99$) for another set of behavioral data (Tadin et al., 2019) demonstrating opposite effects of contrast on motion discrimination and segregation, viz., as contrast increased motion discrimination became poorer whereas motion segmentation got better. Taken together our results show that this model is capable of capturing the trade-off between sensitivity and spatial resolution and highlights its implications for motion discrimination and segregation.

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How are objects represented during dynamic occlusion?

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Objects often disappear briefly from sight due to occlusion. Despite these gaps in incoming visual information, we generally have a strong experience that the object persists. This suggests that neural object representations are maintained throughout dynamic occlusion. However, it is unclear what the nature of such representation is and in particular whether it is perceptual-like, reflecting the same features represented when visible, or more abstract, for example, reflecting limited features such as position or movement direction only. In the current study, we used Magnetoencephalography (MEG) data to track how object representations unfold over time, before, during, and after occlusion, by examining when information about a specific object feature is present in the signal. Participants viewed objects differing in shape and colour as they moved on a circular trajectory and could be occluded at one of four possible locations. We used whole-head multivariate pattern analyses across MEG sensors to test when different object features (e.g., shape, position) are present in the neural signal. When visible, information about object identity and position was clearly evident in the MEG signal. Importantly, our data suggest that the neural object representation during occlusion also contains information both about the object's identity and position, at least during the initial stage of occlusion. Uncovering the temporal dynamics of neural object representations throughout occlusion helps reveal how the visual system overcomes perceptual gaps to support the perception of a meaningful, continuous stream of information.

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The Barber-Pole illusion and the peripheral motion processing of line-ends

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In the Barber-Pole illusion (BPI), a drifting 1D texture is viewed through an elongated aperture and the perceived direction of motion is generally along the orientation of the aperture rather than the Fourier component (i.e., orthogonal to the 1D texture). According to the motion-path-integration theory, the BPI results from a greater path-motion energy along the aperture's elongated orientation. Alternatively, the end-stop theory rather suggests that the perceived direction of motion is driven by the processing of line-ends along the contours of the aperture. Although there is good evidence supporting the end-stop theory for foveal viewing, its applicability for peripheral viewing (>10 degrees) has been questioned. The current study investigated the underlying cause of the BPI under peripheral viewing conditions (20 degrees) by systematically manipulating the shape of the aperture, which was an elongated parallelogram. When the long edges of the aperture were not parallel to the drifting texture, the perceived direction of motion was close to the orientation of the long edges (as typically perceived in the BPI) and the orientation of the short edges had little impact on the perceived direction of motion. However, when the long edges were parallel to the drifting texture (resulting in no motion along these edges), the perceived direction of motion was close to the orientation of the short edges. The fact that a small change in the contour orientation of the short edges had little impact on the global shape of the aperture, but drastically affected the perceived direction of motion, suggests that the BPI can be mainly driven by the processing of line-ends along the aperture contour even under peripheral viewing conditions. These results suggests that the BPI viewed peripherally does not depend on the global shape of the aperture per se, but rather on the contours of the aperture.

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Psychophysically estimated low-speed prior expectations match the encoding characteristics of neurons in area MT

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Bayesian inference provides an elegant normative framework for understanding the characteristic biases and discrimination thresholds in visual speed perception. However, the framework is difficult to validate due to its flexibility and the fact that suitable constraints on the prior beliefs and the likelihood functions have been missing. Here we use assumptions of efficient coding to develop a better constrained Bayesian observer model (Wei & Stocker 2015). In the new model, the stimulus distribution links and jointly constrains both the likelihood function and the prior belief. We fit the model to existing psychophysical speed discrimination data, representing discrimination measurements over a broad range of speeds and stimulus uncertainties. Cross-validation confirms that the model fits the data as well as parametric approximations (Weibull fits) of each psychometric curve. The extracted prior beliefs are closely following a power-law function with an exponent of approximately -1 and are much more consistent across subjects than when extracted with a previous model (Stocker & Simoncelli 2006). Furthermore, the efficient coding assumption of the model also makes the

specific prediction that for a power-law prior distribution the neural encoding space should be logarithmic. We tested this prediction by analyzing the speed encoding characteristics of a large population of MT neurons (Nover et al. 2005). We show that the prior predicted by the encoding characteristics (neural prior) very closely matches the low-speed power-law prior extracted from the behavioral data (behavioral prior). Our results demonstrate that a Bayesian observer model constrained by efficient coding not only accurately accounts for the behavioral characteristics of visual speed perception, but also provides a normative account of the logarithm encoding of MT neurons (which gives rise to Weber's law) as the efficient neural representation of a power-law distributed perceptual variable.

Acknowledgements: This work was supported by the University of Pennsylvania.

Attention: Individual differences, spatiotemporal

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The efficiency of visual search for a frequently-changed target is preserved in older adults

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Visual search is a psychological function integral to most people's daily lives. The extent to which visual search efficiency, and in particular the ability to use top-down attention in visual search, changes across the lifespan has been the focus of ongoing research. Here we sought to understand how the ability to frequently and dynamically change the target in a conjunction search task was impacted by age. To do this, we compared visual search performance of a group of younger and older adults under conditions in which the target type was determined by a cue and could change on trial-to-trial basis (Intermixed), versus when the target type was fixed for a block of trials (Blocked). While older adults were overall slower at the conjunction visual search task, and both groups were slower in the Intermixed compared with the Blocked Condition, older adults were not disproportionately impacted by the Intermixed relative to the Blocked conditions. These results indicate that the ability to frequently change the target of visual search is preserved in older adults. This conclusion is consistent with an emerging consensus that many aspects of visual search and top-down contributions to it are preserved across the lifespan. It is also consistent with a growing body of work which challenges the neurocognitive theories of aging that predict sweeping deficits in complex top-down components of cognition.

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Poster Session E > Attention: Individual differences, spatiotemporal > Poster E82

Mechanisms of covert spatial attention in encoding letter combinations

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Shifting and focusing attention is a key mechanism, in the extraction of sensory information, for adaptive behavior. Reading is a perfect example: correctly identifying letters and letter positions within a word is fundamental to word recognition that demands precise attentional selection. We measured the effects of spatial cues in a multi-letter processing task, in order to characterize the differential effects of exogenous and endogenous covert spatial attention on various aspects of encoding letter combinations. A string of 6 letters was presented for 120ms and participants (n=22) were asked to report the letter that was at one post-cued position. Attention was manipulated with pre-cues: exogenous (50ms, peripheral, uninformative) and endogenous (150ms, central, informative). On valid trials, the pre- and post-cue sides match; on invalid trials they mismatch, and on neutral trials all stimuli are pre-cued. Letter recognition accuracy showed a significant cue benefit (valid>neutral) for both exogenous and endogenous cues. The cue benefit was significantly larger with endogenous than exogenous cues. Notably, the benefits were greatest at the shortest cue to target onset interval (50ms) for exogenous and longest (600ms) for endogenous cues. To further understand the differential effects of exogenous and endogenous attention, we categorized errors as position swaps (reporting a letter

from the wrong position) and misidentification errors (reporting a letter that wasn't in the display). On neutral trials, observers were 1.6x more likely to make position swaps than misidentification errors. Interestingly, valid endogenous cues reduced position swap errors more than valid exogenous cues, but we found no significant difference in misidentification errors with both cue types. Our results demonstrate that exogenous and endogenous attention have different effects on the encoding of letter combinations. Endogenous, more than exogenous, attention reduces errors by improving position coding and therefore might be a key mechanism for the development of reading ability.

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Drift Diffusion Modeling of Intentional and Incidental Temporal Selection of Behaviorally Relevant Moments

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When targets appear in a detection task, unrelated but concurrent stimuli will gain a boost in relational memory, the ability to remember the spatial and temporal relationship between items (Turker & Swallow, 2019). This may reflect enhanced perceptual and relational processing of events by temporal selection, resulting in better representations improving subsequent retrieval. However, alternative or additional factors can exist, from improved memory search to simple response bias. We therefore estimated evidence accumulation, response bias, decision threshold, and non-decision time by fitting drift diffusion models (Ratcliff & McKoon, 2008) to response time data on recognition tasks. In five experiments, three previously reported in Turker & Swallow (2019), participants encoded visual scenes while performing a simultaneous detection task on an unrelated stream of target and distractor cues (male and female faces) appearing over the left or right half of the scene. Some participants were asked to also encode face identity (intentional face encoding), while others were not (incidental face encoding). Participants were later asked to indicate which of two scenes had been presented during encoding and to report the identity and the location of the face that was paired with the scene. Across experiments and conditions, evidence accumulation was higher for the background scenes, face identity, and face location when the face was the target gender than when it was the distractor gender. Response bias did not significantly differ across target and distractor conditions. Although evidence accumulation could reflect either improved memory search or enhanced encoding of the images, an fMRI study with a similar paradigm (Moyal et al., preprint), revealed increases in BOLD activity and better classification of stimuli under target conditions during encoding in visual cortex. Thus, combined with our drift diffusion modeling, our results suggest that temporal selection of behaviorally relevant moments enhances perceptual and relational processing.

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The spatial distribution of exogenous attention within and across hemifields

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Exogenous, or involuntary, attention refers to the automatic orienting response to a location where a salient cue has occurred. Many studies have demonstrated that perceptual processing is improved at validly cued locations (cue and target at the same location) relative to invalidly cued locations (cue and target at different locations), with seemingly little influence of visual field location (Henderson & Macquistan, 1993). However, other research on endogenous attention has demonstrated differences in attentional performance within vs. across hemifields (e.g., Alvarez & Cavanagh, 2005; Strong & Alvarez, 2020), suggesting that there are independent attentional resources in each visual hemisphere. To test whether similar constraints are present during exogenous attention we assessed the spatial distribution of exogenous attention in a visual cueing paradigm. Participants ($N = 49$) performed a task discriminating the tilt of a masked Gabor patch target presented randomly at one of four locations evenly distributed around a central fixation point. Shortly prior to the onset of the target, a spatially non-predictive salient visual cue (a white circle outlining the location) appeared randomly at one of the four possible target locations, thus yielding four possible cueing conditions: validly cued, invalid same-hemifield, invalid different-hemifield, and invalid diagonal. Analysis on visual discrimination accuracy showed reliable differences among the cueing conditions ($p< 0.015$) with highest performance for the validly cued locations.

Interestingly, we observed a smaller cueing benefit when comparing valid vs. within-hemifield-invalid relative to valid vs. across-hemifield-invalid, possibly suggesting that the spatial distribution of exogenous attention is constrained by the architecture of the visual system.

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Exogenous Shifts of Spatial Attention Operate at a Finer Resolution than Endogenous Shifts

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Shifts of visuospatial selective attention are limited in spatial resolution (i.e., the necessary spacing between a selected target and distractors; Intriligator & Cavanagh, 2001). Previous research on attention resolution has focused on endogenous selection. Our goal was to measure the resolution of exogenous shifts of visuospatial attention by quantifying the minimum spacing needed for individuals to isolate and select a peripheral item among nearby distractors. In Experiments 1 & 2 (peripheral stimulus diameters of 1° or 0.75°, respectively) participants viewed a circular array of equally spaced, luminance-matched colored disks at 10° eccentricity on a median gray background with a single white RSVP stream at fixation. Subjects monitored RSVP items for one or more target digits and responded via button press. Simultaneously, on each trial a black dot briefly (60 msec) appeared (among the peripheral-colored disks) which exogenously captured attention. After each trial, participants selected via mouse-click the color (from several choices) corresponding to the location nearest to which the black dot had appeared on that trial. Participants in Experiment 2 (M = 49.54%) performed significantly better than participants in Experiment 1 (M = 37.4%) on the color selection task. Responses were compared to an ideal observer model to determine the size of attentional window each subject deployed in response to the exogenous cue. This window size was then used to quantify the minimum stimulus spacing needed for performance to reach 75% correct. Minimum spacing estimates were not significantly different either between Experiment 1 (M = 1.076°) and Experiment 2 (M = 1.051°) or within-subject (across the visual field). These results are 24% (Experiment 1) and 26% (Experiment 2) less than the magnitudes reported in endogenous attention investigations. We conclude that the spatial resolution of exogenous attention shifts allows for a finer grain of selection compared to that of endogenous shifts.

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How exogenous and endogenous attention affect the vertical meridian asymmetry across spatial frequency and eccentricity

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[Goal] At a fixed eccentricity, contrast sensitivity is higher along the lower than upper vertical meridian. This asymmetry is exacerbated at high spatial frequencies (SF) and eccentricities. Exogenous and endogenous spatial attention--respectively, involuntary and voluntary selection of spatial locations without eye movements--differentially modulate contrast sensitivity across SF along the horizontal meridian. Here, we investigated whether and how their differential modulation generalizes to the vertical meridian. We measured the effects of exogenous and endogenous attention on contrast sensitivity along the vertical meridian and across SF and eccentricity within the same observers. [Methods] Observers performed a 2AFC orientation discrimination task. Tilted (±45°) gratings were displayed along the vertical meridian above and below a fixation cross. In Valid conditions, peripheral precues manipulated exogenous attention and central precues manipulated endogenous attention. In Neutral conditions, non-informative precues distributed attention across the vertical meridian. Response cues indicated the target. Four gratings were displayed with one of eight SFs (0.5-11 cpd) and simultaneously at two eccentricities (2°, 6°). On each trial, gratings had the same SF and their contrasts were fixed (based on initial threshold sessions) such that Neutral performance was titrated to a d′ of 1.5 across SF and eccentricity. [Results] Contrast sensitivity was higher along the lower than upper vertical meridian, bandpass across SF and declined with eccentricity. Neutral performance was equated across SF, eccentricity and meridian location (upper, lower). Exogenous attention preferentially enhanced SFs higher than those intrinsically preferred in the

Neutral condition at each eccentricity. In contrast, endogenous attention improved SFs both higher and lower than baseline preferences. Each type of attention operated similarly at lower and upper vertical meridians. [Conclusion] Our results provide converging evidence that covert attention differentially shapes spatial frequency sensitivity across and around the visual field, but cannot overcome the asymmetries.

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Differential effects of endogenous and exogenous attention on sensory tuning

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Purpose: Covert spatial attention benefits performance in many visual tasks. Endogenous (voluntary) and exogenous (involuntary) attention can have differential effects on performance. For example, in texture segmentation tasks, endogenous attention always improves performance whereas exogenous attention impairs performance near the fovea (high resolution) but improves performance in the periphery (low resolution). Furthermore, exogenous attention benefits performance at SFs higher than the target's SF, whereas endogenous attention improves performance at SFs below and above the target's SF. Here we investigate whether sensory tuning is differentially affected by exogenous and endogenous attention. Methods: The same six observers completed 15 experimental sessions of exogenous and of endogenous attention while detecting the presence of a vertical grating embedded in noise. Following a valid, neutral, or invalid cue, stimuli were presented at four peripheral locations (7° eccentricity). Whether a target was embedded in the noise was independently and randomly manipulated for each location. A response cue determined the test stimulus. The feature content of the noise was regressed with behavioral responses (reverse correlation) to derive tuning curves for each attentional cue and feature dimension (orientation and SF). Results: Both endogenous and exogenous covert attention improved performance at the attended location and impaired performance at the unattended locations, compared to the neutral condition. Both types of attention enhanced the gain of the target orientation and maintained tuning width. Endogenous attention enhanced the gain of SFs below and above the target's SF, whereas exogenous attention shifted peak sensitivity to higher SFs and enhanced the gain of SFs higher than the target's SF. Conclusions: Both types of covert attention modulate orientation similarly. However, endogenous attention flexibly enhances low and high SFs whereas exogenous attention inflexibly enhances higher SFs. These changes in sensory tuning can underlie the differential performance effects of endogenous and exogenous attention.

Acknowledgements: Funding: NIH R01-EY019693 to M.C.

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Web-Based Assessment of Visuospatial Processing Speed Across the Lifespan

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While declines in visuospatial processing speed in adults over 65 years are well documented, more fine-grained lifespan changes are not well characterized. Here we developed a novel visuospatial processing speed task for web-based platforms adapted from the Useful Field of View paradigm. This dual task required both discriminating a tumbling E's orientation at fixation and localizing a blue diamond among a peripheral ring of distractors (conjunction search) on each trial. An adaptive bestPEST threshold estimation was implemented to determine stimulus duration thresholds in 50 trials. Data was collected from 4,718 volunteers between 12-62 years old (55% male) on TestMyBrain.org. Binned average thresholds as a function of age were calculated using a 3-year sliding window. The average thresholds were well modeled by a segmented linear function with peak performance occurring at 22 years (95%CI: 19-28) and increasing by approximately 9ms/year afterward. This is reflected in the observed doubling of threshold durations across 20 vs. 60-year-old participants (412ms vs. 817ms). As this task assumes fixed slope and lapse rate parameters for the Weibull function used in the bestPEST algorithm, a simulation study was also completed to assess how deviations in these parameters from an individual's best-fitting parameters impact the stability of threshold results. Over 7 million simulations

were completed varying combinations of threshold, slope, and lapse rate parameters to determine the probability of a correct response when the bestPEST was run using the fixed slope and lapse rate. Results show strong correlations between true and estimated thresholds for all slope/lapse rate combinations (r = 0.84-0.99). Comparisons across pairs of thresholds show that ordinal rankings for threshold differences >20% were preserved over 90% of the time. These simulation results validate that the slowing observed in our online data reflects age-related declines in processing speed and use of adaptive algorithms for web-based testing platforms.

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Effects of Age are Not Uniform Across Cognitive Processes: A Repeated-measures ERP Study

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Does aging affect neural processing similarly across cognitive tasks or does it target specific cognitive processing mechanisms? Frequent findings of increased latency and reduced amplitude in older adults suggest the possibility of a general mechanism. However, no study has tested this hypothesis directly by comparing processing within the same individuals across multiple tasks. In our study, older (ages 60-85) and younger (ages 18-30) adults participated in four tasks (CORE; Kappenman et al., 2020) while EEG was collected: face processing (N170; one-back for faces, cars, scrambled faces, and scrambled cars), attention and categorization (P3; visual odd-ball), semantic processing (N400; word-pair semantic judgment), and error processing (ERN; flanker task). Each group had 17 participants with complete data across all tasks. Results showed differential age-related condition effects for different tasks. For the N170, older and younger adults showed similar amplitude differences between faces and cars at P07/P08 electrodes. For the ERN, no significant age-related differences were found for error versus correct response amplitude differences at central electrodes. In contrast, age-related differences were found for the P3 and N400 ERPs at centroparietal electrodes in terms of smaller condition amplitude differences and less focal distributions of neural responses. Specifically, older adult amplitudes differed from younger adults for the target, but not the standard, condition (P3) and for the related, but not the unrelated, word-pair conditions (N400). An age by task interaction of standardized difference wave amplitudes confirmed significant age-group differences for the P3 and N400, but not for the N170 and ERN. Thus, aging does not affect neural processing similarly across these four cognitive tasks within individuals.

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Hemianopic field loss and change blindness in simulated driving

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Individuals with hemianopic field loss (HFL) fail to perceive visual information that falls within the blind portions of their visual field. This places additional burden on memory and attention to represent information in their blind visual field, which may make visual changes in the scene more difficult to detect. Failing to detect changes could have serious implications, especially in the context of driving. We used a driving simulator paradigm to test the hypothesis that individuals with HFL would be more susceptible to change blindness than those with normal visual fields (NV) A change blindness experiment was conducted (HFL, n=11; NV, n=10) where changes (i.e., pedestrians appearing) were triggered based on the driver's gaze location. Pedestrians appeared equally on the left and right and were triggered to occur only when looking in the opposite direction from the side of the change. Gaze was tracked while driving and used to ensure that the location of the change was visible (in the seeing hemifield) before and after the change occurred. Those with

HVFL had more change blindness than those with NV [18.0% v 9.4%, p=0.007] and more change blindness to pedestrians appearing in their blind than seeing hemifield [31.0% v 12.4%, p=0.01]. Further, there was more change blindness for events in the seeing hemifield for those with HFL than NV [p=0.046]. Consistent with our hypothesis, these results suggest that individuals with HFL are more susceptible to failures of awareness (e.g., change blindness) than individuals with NV, which may place them at higher risk for motor vehicle crashes where the driver fails to notice the other road user (looked-but-failed-to-see incidents).

Acknowledgements: Funding: R01-EY025677

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Individual Differences in Objective and Subjective Socioeconomic Status, and the N2pc

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The effects of one’s socioeconomic environment during development on the neural correlates of selective attention has been a developing area of research (Wray et al., 2017). However, there is a paucity of research on the long-range impacts of these differences in young adulthood. Additionally, while there is research using objective measures of socioeconomic status (e.g. education level) and attention, subjective measures (i.e. perception of status in relation to others) have rarely been utilized. The current study examines the effects of both objective and subjective measures of socioeconomic status on visual selective attention as indexed by the N2pc event related potential component. A large sample (n=203) of young adults completed a visual search task while event related potentials were collected. Separately, participants provided information regarding objective socioeconomic status, specifically maternal education which has been used as an effective proxy of objective status (Stevens et al., 2009). Participants also completed the MacArthur Subjective Socioeconomic Status scale, indicting where they placed themselves in relation to others in the U.S. and in relation to other students at their universities. A linear regression with objective and subjective measures of socioeconomic status as predictors of N2pc Difference Wave amplitude was significant (R2=.050, F(3, 199)=3.51, p=.016). Consistent with previous research in children, results demonstrate a relation between objective socioeconomic status and N2pc amplitude. Moreover, a subjective measure of socioeconomic status (status in relation to others in the U.S.) was also related to N2pc amplitude, with higher subjective perceptions of socioeconomic status related to a larger N2pc attention affect. These finding suggest that one’s socioeconomic environment, be it objective or subjective, is an important factor in shaping selective attention into adulthood. Importantly, this research suggests developmental differences early in life can have long term implications for attention, an essential component of other cognitive processes.

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Improving left visual field attention in right unilateral stroke patients

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In neurotypical individuals, attention to the left visual field increases after prolonged attention to the right visual field. The visual field specific increase is likely a byproduct of homeostatic rebalancing of visual field attention following sustained imbalance in attention between the visual fields. Individuals who suffer right unilateral stroke can experience a spectrum of left visual field inattention, from mild to severe (hemispatial neglect). We aimed to cause a rebound in attention to the impaired left visual field of stroke patients, following an attention demanding task to the unimpaired right visual field. First, we characterized participants’ (n=11) contralesional inattention using four tests. Next, across two counterbalanced sessions, participants performed either the intervention: attention isolated to right visual field only using right unilateral

multiple object tracking (MOT) for 30 minutes, or the control: attention maintained bilaterally using bilateral MOT. Fixation was monitored with an eye-tracker. We tested bilateral MOT before and after to determine visual field specific intervention impact. When participants were considered as one group, the intervention had no impact on attention in the impaired left visual field. However, when dividing participants between severe or mild inattention, we found participants with mild inattention (n=6) experienced a 13% increase in attention in the impaired left visual field. Attention was unchanged in the unimpaired right visual field across intervention, indicating benefit could not have transferred to the left visual field due to training. More likely homeostatic rebalancing, following the intervention-based exacerbation of the already existing visual field attention imbalance, caused a left visual field attention increase. The large increase in attention to the impaired visual field indicates this intervention could be a strong candidate for rehabilitation in mildly affected patients. Future studies will examine the longevity and generalizability of such an intervention to other attention demanding tasks.

Acknowledgements: Data collection funded by MossRehab Research Resources

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Depth-specific IOR effect when attention shifts from far to near space relative to viewer

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Inhibition of return (IOR) is a phenomenon where responses to a peripheral target are delayed if the target appears more than 300ms after a cue, when the cue appears in the same peripheral location compared to a cue appearing in the opposite side of central fixation. IOR has been extensively shown to operate in 2D scenes. However, it is not fully understood whether IOR is determined by relative location between cue and target in retinal coordinates or world coordinates. Such a question can be studied by examining IOR in 3D scenes. We compared IOR when cues and targets appeared at same or different depth planes and when depth information was provided by monocular cues (mostly linear perspective) presented on a projection screen. In the 3D condition, cue and target (of identical retinal size) appeared atop of placeholders that intersected with a ground plane. When the cue and target appeared at different depths, a vertical offset was created on-screen, which was a potential confound to depth perception. We removed the contribution of this confound by contrasting the 3D condition with a 2D control condition that matched cue and target positions but removed all context simulating 3D space. Results showed that the magnitude of IOR decreased for the different-depth condition compared to the same-depth condition in 3D displays. The magnitude of IOR also decreased as a function of vertical offset in corresponding 2D displays. Most importantly, such magnitude reduction in 3D displays was higher than that in the corresponding 2D displays, but only when the difference in depth was caused by the target appearing at a nearer position (closer to the viewpoint) compared to the cue. We thus have identified a depth-specific IOR effect, which occurs only when attention shifts from far to near space relative to the viewer.

Acknowledgements: Natural Sciences and Engineering Research Council

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The Impact of Image Contrast, Blur, and Presentation Pattern on Visual Sustained Attention

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Deficits in sustained visual attention are common in various populations, such as older adults or individuals with traumatic brain injury, leading to measures of sustained attention being standard in neuropsychological batteries. However, many of these populations also have higher rates of primary visual function deficits, highlighting the need to determine the extent to which performance on sustained attention tasks is dependent on primary visual functions. This study investigated the impact of image contrast and resolution on an adapted version of the gradual-onset continuous performance task where participants discriminated between city and mountain images. Healthy, normal vision participants (N=36; mean age=20.8) completed two blocks of 600 trials of this discrimination task where images were either blurred or reduced in contrast to simulate low vision deficits. Each block tested six levels of image degradation (Blur filter radius: 0/5/10/15/25/40 pixels; Contrast rescaled intensity range: (1/0.164/0.128/0.092/0.056/0.020). For half of the subjects, scenes faded from one to the next every 800ms (dynamic condition) while the other half saw static scenes that stayed on until a response was made (static condition). Hierarchical regression models were fit to the data comparing models with separate slopes and intercepts to models with a shared slope parameter. For the contrast conditions, accuracy was found to decrease at a faster rate in the dynamic condition relative to the static condition where few errors were made across all six contrast levels ($p=0.0016$). However, for the blur conditions, accuracy was found to decrease at a similar rate regardless of how long stimuli were presented ($p=0.1889$). While reducing image contrast had little impact on performance for static presentations, these results demonstrate that under dynamic conditions more representative of real-world environments, changes in both image contrast and resolution lead to performance deficits that may be misinterpreted as attentional failures.

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The Role of Kinematic Properties in Multiple Object Tracking

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[Introduction] People commonly track objects moving in complex natural displays and their performance in the “multiple object tracking” (MOT) paradigm has been used to study this visual attention task for over three decades. Given the theoretical and practical importance of object tracking, it is critical to understand how people solve the correspondence problem to track objects; however, it remains unclear what information people use to achieve this feat. In particular, while people can track multiple moving objects based on their positions, there is ambiguity whether people can track objects via higher order kinematic information such as velocity. [Method] We explicitly test whether people can use instantaneous velocity direction to solve the correspondence problem during multiple object tracking when positional information is completely ambiguous. And we further test whether acceleration direction can also be used for tracking when object position and instantaneous velocity direction are both uninformative. [Results] We show that people use velocity direction when it is necessary to disambiguate targets from distractors. However, tracking via velocity is less accurate than tracking via position alone, indicating that velocity simply does not provide as an informative cue as position. Furthermore, observers fail to use acceleration to track objects, even though they can reliably detect the acceleration cue. This pattern of results indicates that the failure to use acceleration during object tracking reflects which kinematic information is used to resolve correspondence. Finally, we demonstrate that the extent to which velocity, but not acceleration, is used varies with “kinematic load” – the number of object pairs requires velocity information simultaneously. Together, these results indicate a hierarchy of kinematic information for tracking – position is most precise and most useful, but velocity can still be used to solve the correspondence problem; acceleration, in contrast, seems to be largely not used for multiple object tracking.

Multisensory Processing 2

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Exposure to congruent or incongruent audiovisual stimuli modulates observers’ prior about a common cause for vision and audition

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We live in a multisensory world: to estimate properties of the environment, for example, the location of a barking dog, there are usually multiple sensory cues available to base the estimate on. The final estimate of the dog's location depends not only on the multisensory cues, but also on a crossmodal common-cause prior—a prior belief accumulated from past experience about cues in different modalities coming from a common source. We examined whether short periods of exposure (160 trials) to consistently spatiotemporally congruent (association) or incongruent (dissociation) audiovisual stimuli affect observers' common-cause prior. Crucially, we ensured that the audiovisual stimuli were perceptually rather than physically (mis-)aligned by measuring and adjusting each observer's relative auditory and visual localization biases. During every trial of the exposure phase, observers localized the stimulus of one modality, cued after stimulus presentation, by adjusting a visual cursor and occasionally made an additional common-source judgment. To measure common-cause priors before and after the exposure phase, observers localized and judged the unity of synchronously presented audiovisual stimuli with a pseudo-random spatial discrepancy. To extract observers' common-cause prior, we fitted a Bayesian causal-inference model jointly to localization responses and unity judgments made before and after the exposure phase. Significant changes in the common-cause prior emerged after the association and dissociation phases. The majority of observers showed a decrease in the common-cause prior after the dissociation phase; yet, an increase was found, too. Both effects have been reported separately in previous studies. Simulations of the causal-inference model for these opposing results will be discussed. Our findings provide robust evidence for experience-dependent updates of the common-cause prior after short periods of exposure to audiovisual stimuli.

Acknowledgements: NIH EY08266

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Occlusion of dynamic objects influences visual expectations of ensuing sounds

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Moving objects help generate expectations about accompanying sounds and can facilitate early auditory processing of stimuli that match these expectations. At times, a moving object may become occluded by an obstruction; it is unclear to what extent such disruptions to the visual input affect the expectations about subsequent sounds associated with the visual object. We conducted two experiments that examined how dynamic visual input, either fully visible or occluded, influences visual expectations of an ensuing sound. EEG was recorded from adults who passively viewed a red ball that appeared either on the far left or right edge of the display and continuously traversed along the horizontal midline to make contact and bounce off the opposite edge, eliciting a sound at the point of collision. Experiment 1 (n=19) consisted of three conditions: 1) sound with full visual input: a ball was visible when colliding and making a bouncing sound; 2) sound with some visual input: a ball was occluded halfway and not visible during the bouncing sound; 3) sound with no visual input. Experiment 2 (n=17) systematically varied the amount of occlusion to better understand how much visual information is necessary to elicit expectations (AV-full, AV-2/3 – least occluded, AV-1/2, AV-1/3 – most occluded). Our analyses focused on a late slow-wave event-related potential (ERP) measured at occipital electrode sites prior to the onset of the sounds, and revealed differences in the amplitude across the occlusion conditions. In particular, the experiments show that visual occlusion elicits greater slow-wave negativity compared to non-occluded visual input. Overall, these results suggest that occlusion of a dynamic object results in the deployment of neural resources devoted to generating expectations about the timing of an impending auditory event.

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Spatial and feature tuning of serial dependence in audiovisual timing perception

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From speech recognition to music performance, perceiving synchrony and temporal order between auditory and visual inputs is crucially important for our daily life. However, due to the temporal variabilities of signal transmission in the environment as well as sensory processing, the perceptual system has to compensate for such noisy sensory inputs to

achieve stable representations of integrated multisensory events. To solve this problem, the timing system exploits the temporal redundancy of events and biases the perception of current audiovisual lag towards or against previously perceived lags, depending on task or sensory modality (Roseboom, 2019; Van der Burg et al., 2013). The attractive serial effect is consistent with a phenomenon called serial dependence that has been widely reported in visual perception (Cicchini et al., 2014; Fischer & Whitney, 2014; Liberman, et al., 2014). In the present study, we tested the spatial and feature tuning of the serial dependence in timing perception. In the experiment, auditory and visual stimuli were briefly presented with various stimulus onset asynchronies (SOAs), and participants judged which stimulus appeared first. The visual stimulus was presented at a random location along an invisible concentric ring with a radius of 7 degrees. We replicated serial dependence in timing perception: the perceived lag between auditory and visual stimuli was biased toward previously presented audiovisual lags. Furthermore, this serial dependency occurred only when the location of the visual stimulus in the current trial was near the previous stimulus location. In addition to spatial tuning, the serial effect was stronger when the current and previous audiovisual lags were close to each other, indicating the feature tuning of this effect. Our results suggest that the serial dependence in timing perception cannot be explained by generic decision inertia or response biases, but is tuned to sensory properties such as visual location and audiovisual lag.

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Primary visual cortex is activated by spoken language comprehension

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Current accounts of neural plasticity emphasize the role of connectivity and conserved function in determining a neural tissue's functional role even after atypical early experiences. However, in apparent conflict with this view, studies have suggested that in congenitally blind individuals, language activates primary visual cortex, with no evidence of major changes in anatomical connectivity that could explain this apparent drastic functional change in what is typically a low-level visual area. To reconcile what appears to be unprecedented functional reorganization in V1 with known accounts of plasticity limitations, we used functional magnetic resonance imaging (fMRI) to test whether primary visual cortex also responds to spoken language in sighted individuals. We found that primary visual cortex was activated by comprehensible speech as compared to a reversed speech control task, in a left-lateralized and focal manner, in sighted individuals. Importantly, left V1 activation was also significant and comparable for abstract and concrete words, precluding a visual imagery account of such activation, and activation was also not correlated with attentional arousal ratings. Together these findings suggest that primary visual cortex responds to verbal information even in the typically developed brain, potentially to predict visual input. This capability might be the basis for the strong V1 language activation observed in people born blind, re-affirming the notion that plasticity is guided by pre-existing connectivity and abilities in the typically developed brain.

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Visual Cues Reduce Spatial Uncertainty in Multi-Talker Situations

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In social situations where multiple talkers speak from different locations, tracking and segregating conversations can be challenging. We hypothesized that 1) the spatial uncertainty of the talker locations may contribute to listening difficulty; and 2) providing visual cues at the target talker location can facilitate speech recognition by reducing the spatial uncertainty. Subjects with normal hearing and vision (N = 22, 18 to 29 years) listened to simultaneously spoken sentences by three talkers with 10° or 20° separation, from different directions in the horizontal plane. In each trial, subjects attempted to repeat the sentence of a target talker indicated by a fixed starting word. The accuracy decreased from frontal (straight-ahead) to peripheral locations (left or right), and was higher with 20° separations. Word mislocation

appeared to be the primary error. When the target was located at the center position among the three talkers, the mislocation error was the highest. When the target location was indicated by a brief visual pre-cue, the mislocation errors reduced and the accuracy increased. This cue benefit was only significant for the 20° separations. To model the effect of spatial uncertainty, subjects were asked to localize 200ms auditory noise (0.2-8 kHz) or visual white disks (3°) presented at random horizontal directions. Errors in localization (bias and precision) modeled by individual Gaussian functions represented spatial uncertainties for vision and audition at each azimuth. The probability of correctly locating the target talker in the multi-talker task was predicted from three auditory Gaussian functions corresponding to each talker direction. Visual cue effect was modelled by applying a visual Gaussian function to the three auditory Gaussians. This simple model provided close predictions for the multi-talker performance and visual cue benefit. Our empirical data and modeling approach revealed the important roles of both auditory and visual spatial uncertainty in multi-talker situations.

Acknowledgements: Supported by Grant from the National Institutes of Health 1K99EY030145-01A1 to Y-ZX

Poster Session E > Multisensory Processing 2 > Poster E101

Visual experience modulates sensitivity to statistics of reverberation

View Poster | Visit me in Gather.Town Dolphin Room on Monday 3:30 pm - 5:30 pm EDT

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Scene analysis is fundamental to successfully perceiving, interacting with, and navigating through the environment. In the absence of visual information, scene analysis relies largely on auditory signals such as reverberation, the aggregated acoustic reflections from multiple nearby surfaces. Sound sources and the spaces surrounding them are separably coded (Teng et al., 2017), an operation contingent on spectral and temporal statistics of the reverberant background (Traer & McDermott, 2016). It remains unclear how these perceptual heuristics develop or how they are influenced by experience. Here we investigated whether visual experience modulates reverberant perception. The experience-dependence hypothesis predicts higher fidelity in early- and congenitally blind listeners, who are more heavily dependent on acoustic cues. Alternatively, the calibration hypothesis predicts that, deprived of a visual “scaffold,” blind listeners would be impaired in reverberant coding. To test these predictions, we conducted an online experiment in which sighted and blind participants listened to pairs of spoken sentences, each convolved with a reverberant impulse response (IR). The IRs were recorded from a real-world space or synthesized to match or deviate from the temporal and spectral features of that same space. Manipulations included the temporal decay rate and the spectral distribution of the IRs. The task was a 2AFC judgment to indicate which of the spaces was “real.” We found that blind as well as sighted participants were highly sensitive to temporal deviations from ecologically valid reverberation, and less sensitive to spectral deviations. Interestingly, while sighted listeners reliably distinguished spectrally altered reverberation at above-chance levels, preliminary results indicate markedly reduced performance in blindness. Some below-chance performance in these conditions suggests a sensitivity to spectral alterations (cf. Voss et al., 2011), but an ambiguity in assigning them to the correct category. Taken together, our results suggest that visual experience modulates representations of auditory environmental statistics.

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Poster Session E > Multisensory Processing 2 > Poster E102

Influences of posture on gravity perception in the audiovisual bounce inducing effect

View Poster | Visit me in Gather.Town Dolphin Room on Monday 3:30 pm - 5:30 pm EDT

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Visual perception is influenced by many factors including naturalistic motion that adheres to Newtonian principles of gravity. Previous research has examined perceptual interpretations of a classic cross-modal phenomenon – the

audiovisual bounce-inducing effect (ABE) – and how it is influenced by gravity congruent motion. The ABE presents two identical objects with opposite trajectories moving in a downwards motion uniformly along diagonals where participants make stream vs bounce perceptual judgments. Perceptual interpretations of ABE vary depending on whether a sound is introduced at the point of coincidence of the two objects' trajectories (i.e., sound increases 'bounce' percepts). These perceptual interpretations are also influenced by factors such as its congruency with Newtonian principles. The present study repeated a previous experiment that examined the effects of gravitational congruency on visual motion perception showing motion dynamics and congruency shift perceptual interpretations for accelerating motion events. In addition, our study altered the body's posture (sitting/laying) so that the visual perception of movement was either congruent (sitting) or incongruent (laying) with Newtonian principles. We hypothesized that perceptual interpretations following gravity congruent perception would show a difference in the 'bounce' percept if the visual perception of downward motion is in the horizontal or vertical plane. Two identical discs moving in downward directions were presented to observers where the discs moved in uniform motion, acceleration, or deceleration. Sound was presented synchronously with point of coincidence or was absent, and each observer viewed these cross-modal events in both a sitting position and a laying position. Participants indicated via button press whether they perceived the discs to be streaming through or bouncing off each other. Our results show the impact of posture congruency with gravitational expectations on visual motion perception while observing different visual motion dynamics. These findings provide evidence of the complexity of factors that influence visual motion perception.

Poster Session E > Multisensory Processing 2 > Poster E103

Online vs. In-Person Investigations of Multisensory Motion Perception

View Poster | Visit me in Gather.Town Dolphin Room on Monday 3:30 pm - 5:30 pm EDT

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Introduction: The global pandemic has required researchers to rely on virtual interactions and online platforms. Others have compared performance between on-line and web-based assessments (questionnaires; see Riva, Teruzzi, & Anolli, 2003), although the reliability of conducting psychophysical studies via Zoom has yet to be established. The present study investigated the reliability and validity of experimental results collected over Zoom. Methods: An audiovisual motion perception paradigm, previously used in-person, was deployed via Zoom. Participants selected an oddball video that contained varying speeds of two moving discs amongst an array of two other videos with constant motions. One of the videos in each array included a sound (or not in the control condition) that occurred at the collision point of the two discs. In-person findings showed participants reliably detected the oddball video (Kominsky et al., 2017), and that performance was modulated for sound conditions (Soma Tsutsuse, Vibell, & Sinnett, 2020). This paradigm allows for a direct comparison of reaction time, accuracy, and lag across platforms using time-sensitive videos synced with auditory stimuli. Results: In-person results showed that participants were significantly more accurate for conditions without sound compared to with sound, and exhibited faster reaction times for unnatural targets without sound. There was no significant interaction between motion type and sound. Similar results were observed for the online condition. Importantly, when directly comparing performance between in-person and online conditions, no significant effect was observed. Participants of both in-person and online conditions showed similar accuracy rates between testing modalities. Lastly, no differences were found in video presentation times, suggesting no lag differences online compared to in-person. Conclusion: The lack of lag and similarity of results across platforms suggests that experimental data can be collected over Zoom reliably and accurately with this paradigm. Furthermore, the virtual replication reflects promising experimental integrity of online platforms.

Poster Session E > Multisensory Processing 2 > Poster E104

Visual-Emotional Association with Vowel Phonemes: Support of the Gleam-Glum Effect when Paired with Visual Imagery

View Poster | Play Video | Visit me in Gather.Town Dolphin Room on Monday 3:30 pm - 5:30 pm EDT

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Introduction: The Gleam-Glum Effect is the finding that words containing the vowel phoneme /i/ (as in "gleam") are rated more emotionally positive compared to those containing /Λ/ (as in “glum”), an auditory equivalent to Darwin/Ekman’s visually-recognizable facial emotion expressions. The theory is that the same facial musculature that is associated with visually-recognizable emotional expressions also favors production of auditorily-recognizable sounds. The Gleam-Glum Effect has been confirmed in English and Mandarin, and with both real words and pseudo-words. Method: This study develops a new methodology to test the Gleam-Glum Effect using visual imagery. 119 undergraduate participants matched verbally presented monosyllabic nonsense pseudo-words to either a positive or negative cartoon picture. On each trial, a voiced instruction presented two pseudo-words (e.g. “Zeek” and “Zuk”) and two cartoon pictures (e.g. happy dog playing with an inflated ball and sad dog looking at a flat ball). Participants were instructed to match one of the words with either picture. The experiment was run online, with 32 counterbalanced trials per participant. Results: Our principal hypothesis that /i/-words would be matched with positive pictures and /Λ/-words with negative ones was robustly confirmed. Every one of the 64 pseudo-words was matched with the positive or negative picture in the predicted direction by more than 50% of the participants (binomial p=10 to -19) and by an average of 77% of participants ($t(63)=27.47$, $p<0.0001$, $d=6.92$). 94% of the pseudo-words matched at a $p<0.05$ level, with 55% at a $p<0.0001$ level. Discussion: The data robustly confirm our hypothesis, replicating previous research supporting the Gleam-Glum Effect. Our findings are the first to confirm this phoneme-emotion relationship with verbalized sounds and pictures. The results support the idea that the visually-recognizable musculature associated with positive and negative facial expressions also favors production of certain phonemic sounds that listeners recognize and associate with specific emotions.

Acknowledgements: This research was partially funded by a grant from the Arizona State University Honors College.

Poster Session E > Multisensory Processing 2 > Poster E105

The feeling of "kiki": select tactile exposure or visual imagery can enhance abstract audio-tactile crossmodal correspondences, the bouba/kiki effect, early in development

View Poster | Visit me in Gather.Town Dolphin Room on Monday 3:30 pm - 5:30 pm EDT

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The bouba/kiki effect is a naturally occurring association between abstract shapes, spikey or round, and nonsense words, /kiki/ or /baba/, respectively, found across cultures, languages, and different senses (e.e., Spence, 2011). Previously, we found 6-8 year-olds showed weaker audio-tactile (AT) associations than adults between heard nonsense sounds and felt abstract shapes, even after explicit instruction on how to optimally explore shapes or twice as much tactile exposure (Chow et.al, in review). Interestingly, AT associations were strengthened if participants first matched the same non-sense sound to complementary seen shapes (audio-visual) or the same felt shape to complementary seen shapes (visuo-tactile). Given that both these conditions provide prior visual exposure, and that early-blind-adults show abnormal AT associations (i.e., Fryer et.al., 2014), we considered if visual experience is critical or if what matters is highlighting relevant shape features, something more automatic in vision than touch. We tested if prior tactile-only (TT) exposure or prior imagery of shapes (IT) could enhance AT associations. In TT, children matched a smaller shape to one of two larger shapes. Felt shapes differed in 2D contour, not texture or material properties. In IT, children imagined if a cloud or star, matched a felt shape. Following 4 trials of TT or IT exposure, children judged which of two felt shapes, one round/one spiky, matched a sound (16 trials). Association strength was quantified as the proportion of trials a round shape was chosen for /a/ sounds. We found prior TT and TI exposure, which provide no direct visual experience, enhanced AT associations in 6-8 year olds. These results suggest that direct visual experience of abstract shapes may be sufficient, but not necessary, in forming the abstract AT associations tested here. Such audio-tactile associations are weaker and generally emerge later than visuo-tactile associations (e.g., Gori et.al., 2008; Streri & Spelke, 1979).

Acknowledgements: UMass Boston Office of the Dean award and UMass Boston undergraduate research funds

Poster Session E > Multisensory Processing 2 > Poster E106

Does color change the identification of color-flavor pairs?

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College, CUNY

To examine how color affects the identification of flavors, we created a new experimental design, measuring flavor identification while manipulating the probabilities that color cues are associated with flavor outcomes. Stimuli were mixtures with varying relative proportions of two fruit flavorants, either banana+peach (five subjects) or orange+watermelon (another five subjects). The mixtures could be colored either green or red, such that color was a reliable, although not perfect, predictor of the greater component in the mixture. In one condition, red and green were equally associated with their flavor outcomes, while in the other two conditions, one color or the other appeared more frequently. We found, in line with predictions, that subjects used color to improve identification rates. Moreover, also in line with predictions, flavor identification rates were associated with changes in the underlying joint probabilities of color cues and flavor outcomes in the three conditions. From the perspective of statistical learning, these results are consistent with the view that the effect of color on subject's identification of flavor depends on contiguity (conjoint probability) or sensitivity (conditional probability of associated color, given specific flavor), rather than validity (conditional probability of associated flavor, given specific color).

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The effect of spatial frequency on visual-vestibular conflict detection

View Poster | Visit me in Gather.Town Dolphin Room on Monday 3:30 pm - 5:30 pm EDT

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Perception of a stable visual environment depends on mechanisms that monitor the agreement between visual and non-visual cues to head movement. Visual cues include a combination of optic flow and oculomotor signals needed to bring retinal motion into head coordinates. Non-visual cues include vestibular signals as well as efference copies of motor commands to rotate the head on the body. Here we investigate specifically how characteristics of the visual scene impact observers' ability to detect visual-vestibular conflict. Experiments were conducted using a head-mounted display (HTC Vive Pro Eye) with fixation behavior monitored by its embedded eye tracker, and head-movement was captured using an external motion capture system (Optitrack Prime 13). On each trial, participants made active yaw head movements of ~30 deg over 1.5 sec while fixating a scene- or head-fixed point. During the head movement, the gain on the visual scene motion was manipulated. Participants were asked to report whether the gain was too low or too high, that is, if the environment appeared to be moving with or against head movement, respectively. Fitting a psychometric function to the resulting data yields the gain perceived as stationary (PSE) and the range of gains that are compatible with perception of a stationary visual environment (JND), referred to by Wallach as the Range of Immobility. Participants were tested using a virtually rendered optokinetic drum with either a low or high-frequency stripe pattern. Our results show lower visual gain (PSEs) in the high-frequency condition suggesting greater perceived speed of scene motion consistent with the known effect of spatial frequency on perceived speed of retinal image motion. Sensitivity to conflict was also reduced (higher JND) in the high-frequency condition suggesting increased signal-dependent noise on estimated scene motion.

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Poster Session E > Multisensory Processing 2 > Poster E108

Neural correlates of spontaneous non-optic vision in a blind individual

View Poster | Visit me in Gather.Town Dolphin Room on Monday 3:30 pm - 5:30 pm EDT

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The brain is capable of producing visual experiences in the absence of retinal input (e.g. mental imagery and hallucinations). We present an unusual demonstration of this ability: a 34-year-old woman, NS, who developed persistent and complex vision-like experiences after losing her sight to a rare retinal degeneration disease. Unlike the hallucinations in Charles Bonnet Syndrome, these experiences are consistent with her environment. After receiving cues of the presence of an object, either through proprioception or haptic interaction, NS "sees" an iridescent representation of the object's form. Unlike imagery, these representations are involuntary and persist as long as she understands the object to be within her line-of-sight. To characterize the neural correlates of these visual experiences, we used 3T fMRI to record BOLD signal while NS completed a task evoking visual perceptions. NS, and a sighted control, placed auditory-cued 3D objects on a plexiglass tray that held the object suspended in their field of view. Subjects then observed the object without touching or movement for 4 seconds: through veridical vision for control, and through "non-optic vision" evoked from prior haptic feedback for NS. This was followed by imagery runs, where subjects completed the motion of placing objects but imagined seeing them instead. A GLM analysis found significant (pFWE<0.05) clusters of activation during object viewing within the visual cortex and nearby temporal and parietal regions of both subjects. The presence of increased activity in visual areas of NS's brain while "seeing" the objects is consistent with her reported vision-like experience. During imagery, activity was attenuated and more confined to the higher visual areas. This represents the first neuroimaging account of such advanced cross-modal non-optic sight in a blind patient, and further supports visual perception being a generative process that depends as much on top-down inference as on retinal input.

Acknowledgements: Funding provided by National Institute of Health grant R01 MH112583

3D Perception: Models, neural mechanisms

Poster Session E > 3D Perception: Models, neural mechanisms > Poster E121

Why do line drawings work? A realism hypothesis

View Poster | Play Video | Visit me in Gather.Town Egret Room on Monday 3:30 pm - 5:30 pm EDT

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Why is it that we can recognize objects and understand 3D shapes from line drawings, even though line drawings do not exist in the natural world? One theory is that we learn line drawing perception, just as we learn written language (Goodman 1968). Yet, even observers who have never seen pictures before can recognize objects in line drawings, e.g., Kennedy and Ross (1975), Jahoda et al. (1977). According to a more recent theory (Sayim and Cavanagh 2011), line drawings activates edge receptors in V1 in order to produce the same percepts as corresponding natural images. However, this theory does not account for the many differences between edge images and natural images, e.g., natural images often have different edges from line drawings. We hypothesize that the visual system perceives a line drawing as though it were a realistic image under a specific type of lighting and material conditions. This hypothesis is based on Abstracted Shading (DeCarlo 2003, Lee 2007, Pearson and Robertson 1985), which shows how plausibly realistic conditions can produce drawing-like images, and is known to be predictive of hand-made drawings (Cole 2008). In other words, basic line drawing styles work because they are visually similar to plausibly-realistic images. This similarity applies to all visual features, not just edges. More generally, we hypothesize that basic line drawing perception is a consequence of realistic image perception, independent of the perceptual mechanism (e.g., edge receptors). We test this by showing that a computer vision model trained only on real images can infer depth from line drawings. These hypotheses suggest new ways to understand line drawing perception as a special case of natural image perception.

Poster Session E > 3D Perception: Models, neural mechanisms > Poster E122

Neural representation of multiple visual stimuli moving transparently at different depths in cortical area MT

View Poster | Visit me in Gather.Town Egret Room on Monday 3:30 pm - 5:30 pm EDT

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Visual motion and depth provide important cues for image segmentation. We characterized how neurons in the middle-temporal (MT) cortex represent multiple moving stimuli and how depth cue contributes to segmentation. We recorded

from neurons in area MT of two macaques. The visual stimuli were overlapping random-dot patches moving in two directions separated by 60° or 120°. One patch was presented at a near disparity (-0.1°) and the other at a far disparity (0.1°). We varied the vector-averaged direction of the two patches to characterize response tuning to the bi-directional stimuli. We also measured the direction tuning to the individual patch. The animals performed a direction discrimination task to report the direction of one of two patches at a cued depth. The first animal performed slightly but significantly better for discriminating the direction of the near-surface, whereas the second performed equally well for discriminating the direction of either surface. The neuronal responses to the bi-directional stimuli were markedly different between the two animals. The response tuning of the first animal showed a significant bias toward the near-surface (p<10-11), regardless of whether a neuron preferred a near or far disparity, or which surface the animal was cued to attend. In contrast, the response tuning of a neuron in the second animal tended to bias toward the surface that the neuron preferred when presented alone. We found a significant correlation between the response bias and a neuron's preference for the individual surface (Pearson's r>0.43, p<10-9). For both animals, attending to one of the two surfaces pulled the response tuning to the bi-directional stimuli toward the attended surface. We are currently investigating why the neural tuning properties differ between the two animals. In either case, the depth cue caused a biased neural representation toward the individual stimulus component(s) and therefore can facilitate image segmentation.

Acknowledgements: NIH grant R01EY022443, I want to acknowledge McPherson Eye Research Institute for their support for the membership fee.

Poster Session E > 3D Perception: Models, neural mechanisms > Poster E123

Visual Skills and Reading Ability: Role of Functional Binocular Vision (FBV)

View Poster | Play Video | Visit me in Gather.Town Egret Room on Monday 3:30 pm - 5:30 pm EDT

Maureen Powers[1], William Fisher[2]; [1]Gemstone Foundation, Tarzana CA, [2]University of California, Berkeley

Studies suggest that poor reading can be related to poor binocular visual skills, such as vergence. It has been difficult to relate reading directly to such skills, however, because most datasets lack sufficient quantitative measures of relevant skills. In a prior study, MKP had gathered data from 1,062 students, ages 8-11; each subject had quantitative symptom and optometric measures. On re-examining this dataset with WPF, we constructed a variable called Functional Binocular Vision (FBV), by using a probabilistic approach that prioritized the estimation and comparison of linear measures. Besides demonstrating that FBV is robust and reliable, we also showed that it is not related to visual acuity. In the present study, we examined the relationship among FBV, acuity, and reading. In the original MKP study, a subset of subjects participated in an in-school intervention designed to improve visual skills using a computer program. The program kept track of 10 indicators (latency and accuracy for each of 5 training modules, each relating to a defined visual skill). These students also had sustained oral reading fluency measures taken during the intervention. Regression analysis of FBV variables against oral reading fluency scores had a significant adjusted R squared (R2) of 0.61; when acuity entered the regression equation, the R2 dropped to 0.44. When we examined the variables that changed with visual skill training, we found that binocular (FBV) and symptom (CISS) scores changed with reading, but acuity did not. We conclude: (a) Functional Binocular Vision (FBV) is a robust and useful construct that can predict oral fluency reading performance independent of Snellen acuity, and (b) training visual skills can improve reading outcomes.

Acknowledgements: Original data collection supported by NIH R01 EY017414 to MKP

Poster Session E > 3D Perception: Models, neural mechanisms > Poster E124

Functional specificity of attentional modulation in the disparity domain

View Poster | Visit me in Gather.Town Egret Room on Monday 3:30 pm - 5:30 pm EDT

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It has been suggested that absolute disparity cues, unlike relative disparity cues, are perceptually inaccessible (Chopin et al., JVis, 2016). If so, processing of absolute disparity information should be less affected by manipulation of attention. Steady-state visual evoked potentials were recorded (N=20) in response to dynamic random dot stereograms (DRDS) alternating at 2 Hz between a flat plane at zero disparity and a 0.5 cpd crossed-disparity sine-wave grating. Disparity was measured at 10 equal log steps. In one condition, participants attended to monocular nonius lines at fixation and pressed a button when a color change occurred. In a free attend condition, participants attended to the DRDS stimulus while maintaining fixation with no button presses. Evoked responses were robust at the first four harmonics of the stimulus frequency (1F, 2F, 3F, 4F). The disparity response function at 1F in the free attend condition was leftward shifted relative to the attend nonius condition, consistent with an input-gain mechanism. The 3F and 4F responses showed no effect of attention. We hypothesized that the unmodulated 3F and 4F signals came from the leading edge of the response and conducted a follow-up experiment to determine the timing of the task effect and the relative timings of absolute and relative disparity encoding (N=9). The disparity grating response (relative disparity) started at around 100 ms and attention began to modulate the response around 50 ms later. Responses to a disparity plane (absolute disparity) and grating diverged at the same ~150 ms latency. Importantly, the task had no effect on the response to the absolute disparity condition at any latency. Our results suggest that the earliest disparity responses represent the encoding of absolute disparity and that responses to absolute disparity are unaffected by attention, whilst responses to relative disparity, once they have been extracted, are modulated by attention.

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Poster Session E > 3D Perception: Models, neural mechanisms > Poster E125

A unified model for binocular fusion and depth perception: Stereo spatial resolution and disparity variance limits

View Poster | Play Video | Visit me in Gather.Town Egret Room on Monday 3:30 pm - 5:30 pm EDT

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Recently, we proposed a unified model for binocular fusion and depth perception and tested it with frontoparallel stereograms (Ding & Levi, Vision Research 2021). At each location, the model consists of an array of disparity detectors, each with different preferred position and phase disparities. The phase-disparity detectors compute interocular misalignment and provide phase-disparity energy (binocular fusion energy) to shift the readout of disparity detectors along position disparity space until the misalignment is eliminated; sensory fusion is achieved locally. After sensory fusion, the combination of position and possible residual phase disparity energies is calculated for depth perception. Binocular fusion occurs at multiple scales following a coarse-to-fine process. At a given location, the apparent depth is the weighted sum of sensory readout shifts combined with residual phase disparity in all spatial-frequency channels, and the weights depend on stimulus spatial frequency and contrast. To test the model with more complex depth profiles, we performed experiments using dynamic band-pass noise stereograms (dBNS, central spatial-frequency = 0.75, 1.5, 3 or 6 cpd and one octave bandwidth) with disparity corrugations of 0.094, 0.188, 0.375, 0.75, or 1.5 cpd. Our results, consistent with previous studies using broadband dRDS (Kane et al. 2014, Peterzell et al. 2017), show that stereovision has poor spatial resolution and limited disparity variance; the Dmin corrugation amplitude has a bandpass property and Dmax has a lowpass property. Using narrow-band dBNS, we also revealed that the Dmin amplitude depends on corrugation/carrier spatial-frequency ratio; best performance occurs when corrugation frequency is 4-8 times lower than the carrier frequency. Model simulations show that the unified model without late-stage filters has a lowpass property for depth corrugation perception. After including late-stage bandpass filters, the model predicts band-pass properties for Dmin corrugation amplitude and low-pass properties for Dmax amplitude, consistent with our experimental data.

Acknowledgements: National Eye Institute grant: R01EY030544, R01EY020976

3D Perception: Real and virtual environments

Poster Session E > 3D Perception: Real and virtual environments > Poster E126

Distance Influences Affordance Perception of Standonability in Virtual Reality

View Poster | Visit me in Gather.Town Egret Room on Monday 3:30 pm - 5:30 pm EDT

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Hajnal, Rumble, Shelley-Tremblay, and Liu (2014) have discovered that the presence of a flat surface at a steep angle in front of an observer during quiet stance stabilized posture and increased movement complexity. Was this effect due to slant or distance from the eye? The present study was designed to test the effect of both in virtual reality using an affordance task. A virtual sloped surface was presented frontally at different geographical slants (0°-90°) and at three egocentric distances (near, mid-range, and far). Participants decided whether the ramp supported standing (affordance judgment) and how steep the slope was (angle judgment). Head movement data and response time was recorded from the Oculus Rift VR headset. The perceived action boundary computed using probit analysis was around 30 degrees for far distances and overestimated for near and mid distances (35 and 33 degrees, respectively). Response time for affordance judgments was the longest at the action boundary. For angular judgments, response time was longest at 45 degrees, the arithmetic midpoint of the stimulus range. Mean magnitude and standard deviation of head movements remained constant across slant angles for the far and mid-distance range but was lowest around task-relevant transition points for the near distance. Due to the brevity of responses, we could not use multifractal parameters, so effort-to-compress (ETC; see Nagaraj & Balasubramanian, 2017) was computed as a measure of complexity. ETC was minimal at transition points for the two corresponding tasks for near distances. Spatial proximity may have been a crucial performance factor, as it is within action-relevant distance. The results show that movement complexity deteriorates around task-relevant transition points independent of mean magnitude and variability of postural sway, potentially signaling task difficulty. The results demonstrate the importance of movement parameters in specifying perceptual performance in affordance tasks.

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Poster Session E > 3D Perception: Real and virtual environments > Poster E127

Testing the generality of depth tracking deficits in realistic virtual environments

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The perception of depth motion is critical for interacting with a dynamic three-dimensional (3D) world. Surprisingly, when only binocular cues are available, continuous tracking of depth motion is impaired relative to frontoparallel tracking (Bonnen et al., 2017). This impairment was thought to be a result of both geometric constraints and the sluggish nature of disparity processing. Here, we used Bonnen et al.'s continuous 3D tracking task in a rich VR environment to test whether depth tracking deficit persisted in the presence of additional cues to 3D motion. A target object moved in a Brownian random walk through a 3D VR environment (VIVE Pro Eye Headset, 1,440 x 1,600 pixels/eye, 110-degree FOV, 90 Hz refresh rate). Participants continuously tracked this target with a "cursor" object using a hand controller (Valve Index). In the "sparse" environment (a replication of Bonnen et al.), only the target and cursor were visible and only binocular depth cues were available. The "rich" environment contained textured surfaces and objects as depth references. We tested the relative contributions of various cues to 3D motion (motion parallax, retinal size change, disparity, and shadows) in a fully crossed design. Performance was quantified using cross-correlograms between target and response velocities (Bonnen et al., 2015). In the sparse condition, tracking for the depth component was relatively sluggish, replicating Bonnen et al. (2017). With all cues present, depth tracking improved slightly in some cases, but was always worse than frontoparallel tracking. The time lags at peak correlation for the depth CCGs were typically 500 ms or more, while frontoparallel lags were about half that. In the monocular conditions, depth tracking was abysmal with the peak correlations close to zero. These results indicate that while monocular cues can perhaps slightly improve the perception of depth motion, binocular cues are vital.

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Poster Session E > 3D Perception: Real and virtual environments > Poster E128

The role of texture for extracting depth in virtual reality

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In real-world settings, objects and backgrounds have varied textures. The spatial frequency (SF) of a texture is likely an important cue for depth perception. Here, we used bandpass-filtered noise patterns to study the interactions between the texture of targets and backgrounds with different SF combinations in a virtual reality setting. The experiment was programmed using Three.js, a Javascript library to render three-dimensional graphics in a web browser. Wearing an HTC Vive headset that showed separate images to each eye, subjects (n=3) viewed the stimuli, which consisted of 3 tiles placed at a virtual distance of 3m and a background surface 6m away from the observer. Each tile subtended an angle of 3°x3°, with a center-to-center distance of 4.7° between adjacent tiles. In each trial, the targets appeared for 1sec, with one tile positioned closer to the observer, scaled to compensate for monocular cues. The task was to indicate the closer tile with a keypress. The threshold distance from the reference tiles was determined using a staircase procedure and converted to disparity sensitivity. Both the target and background were tested with different combinations of bandpass-filtered noise patterns (0.3, 0.6, 1, 3, and 6 cpd) and also a uniform gray background. With a gray background, reliable thresholds were measured for all target textures except 6cpd. With a textured background, thresholds varied from a virtual distance of 11cm (equivalent disparity ~3 arcmins) to 86cm (~45 arcmins), depending on the condition. The subjects had difficulty discriminating the target from the background when both were 6cpd, which neared the screen resolution limit. We found that the disparity sensitivity has a bandpass shape, peaking at 1 to 3cpd for both target and background. Thus the textures of both targets and background are important for extracting depth information.

Acknowledgements: UHCO Start-up Fund

Poster Session E > 3D Perception: Real and virtual environments > Poster E129

Differences in size and distance perception between virtual reality and the real world

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Virtual reality (VR) promises both naturalism and experimental control for vision science, but how valid is the assumption that perception in VR accurately matches perception in the real world? Recently our group found that size and distance perception for real, tangible objects was affected by expectations regarding objects' familiar sizes. This familiar size effect (FSE) was strongest when participants viewed real objects through a monocular pinhole to minimize vergence and accommodation cues to depth; however, a significant FSE was found even with binocular viewing when oculomotor cues were fully available. Here we repeated the experiment using a commercially available VR system (Oculus Rift) to present typically sized virtual Rubik's cubes (5.7 cm) and dice (1.6 cm), as well as atypically sized virtual Rubik's cubes (1.6 cm) and dice (5.7 cm). Virtual objects were presented in both binocular and monocular pinhole conditions. Participants made manual estimations of the objects' size and distance. Surprisingly, perception of both size and distance in binocular VR was more similar to monocular pinhole viewing than binocular viewing in reality. Specifically, the FSE during binocular viewing was significantly stronger in VR than reality. A likely explanation is that the vergence-accommodation conflict in VR leads to higher reliance on cognitive factors and less reliance on oculomotor cues. These results introduce an important caveat for the use of VR in the study of perception: even though distance cues like vergence are present in VR, they may not be utilized for perception to the same degree as in reality.

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Visual Distance Perception Indoors, Outdoors, and in the Dark

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The ability of 16 younger adults to visually perceive distances in depth was evaluated within three environmental contexts (indoors in the dark, indoors in the light, and outdoors). The observers' task was to bisect an 8m distance interval in all contexts using both monocular and binocular vision. In the outdoor environment, the observers' judgments indicated perceptual compression of farther distances similar to that obtained in many previous studies. In the indoor lighted environment, the observers' judgments were consistent with perceptual expansion of farther distances. Finally, there was a beneficial effect of binocular viewing upon the precision of the observers' repeated judgments, but the size of this effect was large only within the dark environment.

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Recovery of vivid 3D percepts from 125 years of historical motion film and animation clips

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Stereoscopy involves presenting two differentially-offset images separately to left and right eyes. This 2D image information is combined binocularly in the brain to generate 3D depth perception. We introduce the ability to recover and perceive dynamic 3D structure from certain 2D moving pictures, along with advantages of the method. Stereoscopic pairs and film sequences were generated from a wide variety of lateral tracking scenes, including: 1) dolly shots, especially 360 deg dolly arc shots, 2) lateral shots taken while driving, flying, boating, and traveling by rail, 3) ‘bullet time’ time sequence shots, e.g. from ‘The Matrix’, and 4) animations based on 3D models. These were scenes from classic motion pictures, or archival footage of significant historical events. Some demonstrations include 3D versions of the first known tracking shots (Venice, 1896), an early flight by the Wright Brothers (1909), Harold Lloyd’s famous clock scene from 'Safety Last' (1923), the Hindenburg’s last moments (1937), 'bullet time' animation from Speed Racer/MachGoGogo (1966), perigee and apogee images pairs of the moon and of the sun, and scenes generated while orbiting distant planets. In addition to the value of seeing historically important scenes in 3D, the method enables observers to infer depth structure and estimate distance when static monocular cues to depth are sparse or non-existent; it also breaks static forms of camouflage. Moreover, we demonstrate that binocular disparity sequences derived from dolly-arc tracking shots rotating around a subject can generate robust 3D perception, despite the common practice of avoiding such binocular convergence in the stereoscopy field (e.g., Gao et al. 2018 PLoS One). The method holds the potential to quantify real and perceived depth from motion parallax in historical and contemporary popular movie sequences.

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Building 3D scene representations from different viewpoints: A contextual cueing study

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Observers can build representations of panoramic scenes from snapshots (Robertson et al., 2016) and can form scene memories incidentally during visual search (Utochkin & Wolfe, 2018). Here, we used contextual cueing (Chun & Jiang, 1998) to test whether observers could build and exploit a 3D scene representation, acquired from exposure to varied viewpoints of a naturalistic scene, during a visual search task. We tested 29 observers (25 females; Mean = 19.34 years) in an online study. On each trial, observers saw a snapshot of the same computer-generated room, but from a different viewpoint (8 viewpoints total, varied trial-to-trial). In the Same-place condition, the target (a tablet) always appeared in the same relative location (e.g., on the table), no matter the viewpoint. In the Different-place condition, the target appeared in a different location in each viewpoint. (In both conditions, the target’s absolute location on the screen varied, due to the changes in viewpoint.) We collected reaction time data based on two redundant measures: keypress (participants reported the left-right orientation of a small probe that appeared on the target) and gaze latency. Overall, search times improved, nearing asymptote within the first third of the block of 48 trials. We performed a nonlinear (exponential decay) regression, and found a significant effect of condition (keypress: $F(3,84)=25.5$, $p<0.001$; gaze: $F(3,88)=12.4$, $p<0.001$). For keypress data, the Same-place condition had a significantly lower asymptotic search time

(1092 ms) than the Different-place condition (1240 ms), a difference of 148 ms. Gaze latency data showed the same pattern, with significantly lower search time in the Same-place (778 ms) versus Different-place (913 ms) condition, a difference of 135 ms. These results are consistent with contextual cueing, and provide evidence that 3D scene representations (acquired from varied viewpoints) are built incidentally and used to facilitate search.

Acknowledgements: This project was supported by a grant from NIH (R15HD086658)

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Investigating Non-Rigid Structure-From-Motion: A Role for Part-Wise Rigidity?

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While structure-from-motion (SFM) studies have largely focused on the perception of rigidly moving 3D objects, more recent studies have shown that observers are good at perceiving certain kinds of non-rigid transformations (Jain & Zaidi, 2011). Our aim is to understand what types of non-rigid transformations are perceivable in SFM. In previous work (Choi et al., VSS, 2019) we compared the perception of two non-rigid transformations: part-orientation change (part-wise rigid motion, e.g. articulation of limbs) and part-length change. We observed a misperception of length change as orientation change. This misperception existed for each observer over a range of length-change values. Here we further investigated the misperception of non-rigid length change. Stimuli consisted of an ellipsoid with a protruding part (perpendicular to the main body, fully visible in the silhouette) that non-rigidly changed in length as the whole object rotated back and forth. We observed a misperception of length change as a rigidly-attached part with an “illusory” non-orthogonal horizontal angle relative to the ellipsoid. In an adjustment task, observers matched the perceived angle between the part and the ellipsoid for seven levels of length change. We compared the perceived horizontal angle to model predictions based on a reinterpretation of length change as a fixed non-orthogonal angle between the part and the body. We equated the ratios of the projected lengths of the part from the starting length:ending length for both ground truth and reinterpretation. We could then make predictions of perceived horizontal angle for each magnitude of length change. Even with no free parameters, the model closely tracked observers’ data. Together, the results show that the visual system is biased towards part-wise rigid interpretations of SFM (such as biological articulation of limbs).

Object Recognition: Categories 1

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Enhancing simulated prosthetic vision with deep learning–based scene simplification strategies

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Introduction. Retinal prostheses have the potential to restore vision to individuals blinded from retinal degenerative diseases. However, the quality of current prosthetic vision is still rudimentary. In this study, we combined various computer vision models with a psychophysically validated computational model of the retina (Beyeler et al., 2019) to generate simulated prosthetic vision (SPV), and investigated their effects on perceptual performance in scene understanding. Methods. 45 sighted subjects (31 females, 14 males) acted as virtual patients by watching SPV videos depicting 16 different outdoors scenes. Subjects were asked to identify if there were people and/or cars in the scene. Perceptual performance was measured as a function of four deep learning-based scene simplification strategies (highlighting visually salient information, highlighting closer pixels, segmenting relevant objects, and a combination of all three), three retinal implant resolutions (8x8, 16x16, 32x32), and nine different combinations of phosphene size and elongation. Results. Subjects were best at identifying people and cars with the segmentation algorithm (d’=1.13, sd=1.02) compared to saliency (d’=0.07, sd=.66, p<0.001), depth (d’=0.29, sd=0.77, p<.001), and combination (d'=1.01, sd=0.91, p<0.05). Higher implant resolutions (16x16: d’=0.72, sd=0.93; 32x32: d’=0.72, sd=1.06) also improved performance compared to lower resolutions (8x8: d’=0.46, sd=0.87, p<0.001). Performance with the smaller phosphene size (100 µm) was significantly better (d'=0.81, sd=1.02) than larger phosphene sizes 300µm (d'=0.6, sd=0.89, p<0.05) and 500µm (d'=0.52, sd=0.96, p<0.05). Discussion. Our results suggest the importance of considering retinal models to predict realistic prosthetic vision. Critically, highlighting objects and higher implant resolution can improve patients' scene understanding.

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Object Category and Retinotopic Location Differentially Modulate Temporal Dynamics of Category Selective Regions of Ventral Temporal Cortex

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Retinotopy as a putative organizing principle extends throughout high-level visual and category selective areas of ventral temporal cortex, but the dynamic temporal emergence of retinotopic information in these areas is not well understood. Given that individual category selective regions contribute to multiple processing states over time (Ghuman and Martin 2019), an open question is whether the retinotopic sensitivity in these areas demonstrate a similar and related temporal profile. To examine this question, we investigated the time course by which category and retinotopic information is represented in high-level visual areas that are tuned to specific categories. We collected intracranial electroencephalography (iEEG) data from face and word sensitive contacts throughout ventral temporal cortex as patients viewed face and word stimuli arranged around fixation. Results from a series of temporally-resolved multivariate classification analyses demonstrate that both position and category information are represented in category-sensitive areas around 100 ms after stimulus onset. Furthermore, position modulates the degree of category representation via foveal and contralateral visual field biases, and face sensitive contacts show enhanced position sensitivity to face stimuli but not word stimuli. Taken together, these results show a fine-grained relationship between retinotopy and object category that can be used to begin teasing apart the spatiotemporal dynamics in visual cortex.

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Does familiarity influence discrimination? Famous and Inverted Faces and Logos

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We have shown that prior knowledge impacts our ability to discriminate intact images from noise. For example, images that are more probable (Greene et al, 2015) or more familiar (Yang et al, 2020) were better discriminated than less probable or unfamiliar images, respectively. The current study aims to extend the familiarity findings of Yang et al (2020) to faces and inverted stimuli. In Experiment 1, we used two manipulations of familiarity: famous vs. computer-generated faces and upright vs. inverted faces. The task required participants to discriminate briefly presented and masked intact images from scrambled (diffeomorphed) versions of the images. A 2-way repeated-measure ANOVA on d prime scores revealed significant main effects of fame ($F(1,55)=8.95$, $p=.004$) and orientation ($F(1,55)=5.84$, $p=.019$), indicating that famous faces were more easily discriminated from noise than CG faces, as were upright faces compared to inverted faces. Interestingly, there was a significant interaction of fame x orientation ($F(1,55)=5.13$, $p=.027$), such that the fame effect was larger for upright faces compared to inverted faces, suggesting that famous faces lose their advantage when inverted. To test whether the inversion effect was specific to faces, in Experiment 2 we ran the same intact/scrambled task with upright and inverted logos. The results replicated the face experiment results with main effects of fame (i.e. highly familiar logos) ($F(1,22)=23.24$, $p<.001$) and orientation ($F(1,22)=12.66$, $p=.002$). However, for logos, there was no interaction of fame x orientation ($F(1,22)=2.09$, $p=.163$), suggesting that the interaction in Experiment 1 was specific to faces and may stem from the well-established detrimental effect of inversion on face recognition. Together, these data indicate that, although all the intact images are easily recognizable as intact under normal viewing times, familiarity is a powerful modulator of discrimination under brief exposure.

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The interaction of visual properties in object-text displays: How shape and font influence preference and attention

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The human brain often processes visual information from different categories in the environment to create a coherent percept. For both visual objects and texts, subjective preferences for curved shapes and particular fonts have been consistently observed. Do the preferred qualities of visual properties for objects and texts have similar or different influences on subjective preference and attention allocation for visual displays that are consisted of these categories? We combined simple abstract objects and 4-letter nonsense words (e.g., galu, qita) to form novel object-text displays. The objects were either curved or sharp-edged; the words were presented in either preferred or non-preferred fonts. A pilot study showing individually presented objects or words confirmed the differential subjective preferences between curved vs. sharp-edged shapes and preferred vs. non-preferred fonts. In the main experiment, participants (n=24) provided subjective preference ratings to each object-text display ("logo"), while their eye movements were recorded for 2 seconds from the stimulus onset. Critically, we found different effects of preferred vs. non-preferred qualities of shape and font on both subjective preference and eye movements. For subjective preference, higher ratings were found with preferred than non-preferred shapes, and longer response times were found with non-preferred than preferred fonts. For eye movements, while initial attention, as indicated by the first fixations, was more likely directed to word than object components, and was also more likely drawn towards preferred than non-preferred fonts, the first fixations were shorter on word than object components. More importantly, while participants viewed the object and text components for comparable amounts of time, longer viewing time and more fixations were found for preferred than non-preferred shapes, but also for non-preferred than preferred fonts. These results suggest that the preferred qualities of visual properties for objects and texts play different roles on subjective preference and viewing patterns for multi-component displays.

Acknowledgements: This research was supported by a capstone grant awarded to Oliver Heyn by New York University Abu Dhabi.

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Human susceptibility to subtle adversarial image manipulations with unlimited exposure time

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Artificial neural networks (ANNs) have revolutionized multiple fields, and were initially inspired by models of biological neural networks (BNNs). A growing body of work finds similarities between behaviors and representations in ANNs and BNNs. However, despite these similarities and shared foundations, ANNs exhibit surprising properties and failures that are generally believed not to exist in biological networks. One of the most dramatic of these failures is a susceptibility to adversarial perturbations, where a nearly imperceptible perturbation added to an input can cause an ANN to behave in a dramatically different fashion, for instance mislabeling an initially correctly identified school bus as an ostrich. Is human vision also susceptible to adversarial perturbations? Past work has shown that when images with adversarial perturbations of intermediate magnitude (±32 of 256 intensity levels) are shown to humans for a short time (~70 ms), human object classification judgments are perturbed in the same direction as ANN's. Other work has found that humans can identify adversarial examples with large magnitude perturbations and extended exposure times. Here, we find that human susceptibility to adversarial examples extends beyond these settings. We display images with small magnitude perturbations (between ±2 and ±32 out of 256 intensity levels) for an unlimited exposure time. We find that even at the smallest ±2 magnitude, these images perturb human judgments of object class in the same direction as an ANN trained to classify images. These results demonstrate that humans exhibit a peculiarity that was once assumed to be specific to machines, and are suggestive that perception in ANNs and BNNs is more similar than commonly believed.

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The spatial tuning of the visual word form area depends jointly on stimulus type and task demands

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Regions of ventral occipito-temporal cortex (VOTC) prefer certain categories of stimuli at certain locations in the visual field. Activity in VOTC also depends on task demands and the distribution of attention. The visual word form area (VWFA) is one such region, being selective for letter strings near the fovea. In this study we ask whether those three variables – (1) visual field location, (2) stimulus type, and (3) task demands – independently modulate activity in the VWFA. For example, changing the task may simply scale the response all locations by a constant factor, independent of stimulus characteristics. To test that hypothesis, we manipulated all three variables in two fMRI experiments. Participants fixated a dot while letter strings or size-matched shapes flashed at varying eccentricities along the horizontal meridian. Participants were required to either perform a judgment on the stimuli or the fixation dot. In each condition, we quantified the VWFA's "field of view" (FOV) as the portion of visual space in which stimuli evoke a strong fMRI response. Responses in the left hemisphere VWFA revealed complex interactions between stimulus characteristics, position, and task demands. For letter strings, performing a task on the stimuli amplified responses and widened the FOV, but this did not occur for non-letter shapes. Moreover, the FOV depended on font size, being wider when the letters were legible in the parafovea. These patterns did not occur in regions selective for other visual categories, nor in retinotopic visual cortex. In summary, activity in the VWFA reflects an interaction of top-down and bottom-up factors. The VWFA receives top-down enhancement to widen its field of view, but that is not merely related to allocating spatial attention. Rather, the top-down enhancement appears to be specifically engaged when the stimuli are words and the subject performs a reading-related task.

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Considering the Speed and Comprehension Trade-Off in Reading Mediated by Typography

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The quantity of information an individual absorbs each day is rapidly expanding. We consider how everyday people adapt to these demands, reading to maximize speed or comprehension, and the resultant speed – comprehension trade-offs. In a large-scale Interlude Reading experiment, 445 crowdworkers read 12 short passages set to a 12th-grade reading level. They read passages in Times and 5 other randomly selected fonts from a group of 26 total fonts. They read 2 passages per font and answered 3 comprehension questions after reading each passage. We divided each passage into 2 short screens to measure reading speed. We found a significant inverse correlation between reading speed and comprehension per-trial ($R = -0.27$, $p < 0.001$), consistent with a speed-accuracy trade-off. We found a similar correlation when aggregating per font, suggesting that font may mediate the effect ($R = -0.39$, $p < = 0.041$). Font also significantly affected reading speed ($p = 0.018$). Confirmatory analyses on each font's relative speed (ranked speeds per participant) demonstrated a strengthened relationship ($R = -0.48$, $p = 0.011$), suggesting the fonts' design characteristics mediated the trade-off within and between participants. Reading speed rises by 31 WPM over the session, and second screens are consistently read faster than first screens by 31 WPM (both $p < 0.001$). Conversely, passage order and the font did not significantly affect comprehension, nor did they indicate that additional practice could mediate the trade-off. Interestingly, practice effects appear insufficient to overcome an intrinsic speed – comprehension trade-off. Fonts demonstrated the same trade-off in an intra-participant analysis; our results suggest that leveraging typeface design could minimize individuals' trade-offs. Indeed, finding the right font for the reader could improve

individual performance in the context of their reading goal: comprehension or speed.

Improving Reading Outcomes Using Digital Reading Rulers for Readers With & Without Dyslexia

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Recent research reveals that what helps people with dyslexia can also aid the general population. We digitally recreate reading rulers traditionally used as visual aids by readers with dyslexia to study if they may assist all readers. We present Interlude Reading experiments run on crowdsourced participants (19 readers with and 26 without dyslexia). We measure reading speed impacts using three digital reading rulers (underline, gray-bar, and light-box), the standard mouse cursor, and none-at-all. Crowdworkers read passages normalized to a 12th-grade reading level in Open Sans on desktop computers in their everyday reading environment. The passages average 75-words, accompanied by two post comprehension questions. Results show we controlled for participants' comprehension, familiarity, and interest with reading passages. Our findings show that all participants benefited when using a digital reading ruler, gaining, on average, 86 words-per-minute when comparing their fastest reading ruler versus using none-at-all. Also, participants preferred the light-box in terms of enjoyment and ease of use. Readers without dyslexia read fastest using the gray-bar reading ruler or the mouse cursor, gaining 29 and 36 words-per-minute, respectively. Designers without dyslexia have created reading rulers similar to the gray-bar for readers with dyslexia. Notably, readers with dyslexia read fastest using reading rulers designed by dyslexic designers, gaining 23 words-per-minute with the underline, and read faster 62% of the time when using the light-box reading ruler. While readers with dyslexia read 23 words-per-minute slower on average with the light-box, those who read fastest gained 111 words-per-minute. The underline and light-box reading rulers are higher contrast visual aids than the mouse cursor or gray-bar. These results lay a foundation for collaborations where visual aids are co-developed using inclusive design practices to individuate reading rulers to augment human behavior, thus benefiting readers with dyslexia and the general population alike.

PseudoSloan: A perimetric-complexity and area-controlled font for vision and reading research

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Artificial “pseudo-fonts” have found widespread application in vision, cognitive neuroscience and reading research. Pseudo-fonts are designed to resemble the characters (glyphs) of an existing alphabet in terms of a set of common low-level features. A promising metric for matching the low-level features of a pseudo-font to the target alphabetic font is their perimetric complexity (PC). PC in the font context is defined as the sum of the inside and outside perimeters of the glyph, squared, divided by the glyph area, divided by 4pi (Pelli et al., Vis Res, 2006, Watson, Mathematica Journal, 2012). Previous research has found that PC predicts letter recognition accuracy in noise over a diverse range of fonts (Pelli et al., Vis Res, 2006). To link the use of pseudo-fonts to the visual acuity literature, we based our pseudo-font on the design principles developed by Louise Sloan in the 1950’s. Importantly, the Sloan font has been specified for eye chart optotypes by the US National Academy of Sciences, National Research Council on Vision (Adv. Ophthalmol, 1980). We created several hundred candidate glyphs that varied in their PC and ink-area using the Sloan 5X5 font grid. From this larger set, we selected two sets of glyphs that closely matched the letters of the upper-case roman alphabet on PC and area. The PseudoSloan TrueType and OpenType fonts are fully scalable and compatible with any operating system and software that supports these font types. Landolt C, tumbling E optotypes and the 26 roman letters are also included. The PseudoSloan font is available at https://osf.io/qhj2b/?view_only=f919f853cb6b426ebd7daff683cf34c2.

Decoding the orientation of small targets in the periphery using

magnetoencephalography

View Poster | Play Video | Visit me in Gather.Town Egret Room on Monday 3:30 pm - 5:30 pm EDT

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Orientation is one of the most basic visual features encoded in the brain, and many neuroimaging studies have used decoding techniques to reveal how orientation information is represented in the brain. Previous MEG studies have successfully decoded orientation from event-related activity induced by oriented gratings (eg, Cichy et al., 2015; Pantazis et al., 2018). However, the gratings used in these studies are typically very large, extending from fovea to periphery in both visual fields. Further, subjects are generally only shown gratings with a small, fixed number of orientations. It remains unclear if the approach for decoding these large, fixed-orientation gratings can work for small peripheral Gabor patch targets, which are more realistic and psychophysically useful. In this study, we showed 21 subjects small, randomly-oriented Gabor patches at 7 degrees eccentricity in the right visual field, with MEG signals recorded concurrently. We also collected structural MRI data for each subject to augment MEG data with source localization analysis. We used a sliding logistic regression model to decode Gabor orientations at various timings relative to the stimulus onset. Our model achieved an average decoding accuracy that is modestly above chance, but revealed a peaking structure in decoding accuracy over time that is significantly different from chance, which was confirmed with a permutation test. From 0-125ms, decoding accuracy sat at the chance level. From 125-225ms, decoding accuracy consistently increased, then decreased back to chance accuracy by 350ms. This structure mirrors the structure of activations in the contralateral visual cortex after stimulus onset, which peaked around 150-225ms, on average. Our results suggest that increases in decoding accuracy correspond to increased activity in the visual cortex, and that MEG is viable for decoding small peripheral targets. This may improve our future ability to decode more complex peripheral visual stimuli from MEG data.

Poster Session E > Object Recognition: Categories 1 > Poster E144

Co-occurrence statistics from vision and language capture thematic relationships between objects

View Poster | Visit me in Gather.Town Egret Room on Monday 3:30 pm - 5:30 pm EDT

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Thematic relationships have been defined as the grouping of objects together by virtue of their complementary roles in the same scenario or event. Importantly, thematic thinking has been shown to occur implicitly, and can have a strong influence on a variety of cognitive behaviors, including the allocation of visual attention. Here we examined the extent to which an unsupervised machine-learning algorithm trained on object co-occurrence statistics could capture thematic relationships between objects within events. We asked Mturk workers (n=240) to list the most common objects found in 24 events (e.g. “a child’s birthday party”). We then trained several models with a common continuous-bag-of-word (CBOW) architecture, but with different training corpora. The primary question of interest was whether human ratings for objects belonging to common themes were better described by training on visual scenes or text description. Vision-based models were trained on a database of over 22k densely segmented real-world and photorealistic scenes, and captured the frequency of co-occurrence between objects in visual scenes. Language-based models were trained on a database of over 2.6 billion websites, Wikipedia pages, and news articles, that captured the frequency of co-occurrence between objects in written descriptions. For each model, we ranked each target object in an event by the strength of the similarity between the object’s word vector and the vector representation of the event. We found that object rankings provided by language-based models were more strongly correlated with human rankings of objects than the rankings provided by image-based models, though there was unique variability in what scenarios language vs. vision models performed better on. Together these findings reveal the need to reexamine the way in which we define thematic relationships, and point towards the importance of understanding the impact of both visual and textual inputs.

Acknowledgements: This work was supported by NIH grant NIH-RO1-MH113855-01 to JG. EHH is supported by the Department of Defense (DoD) through the National Defense Science & Engineering Graduate (NDSEG) Fellowship Program.

Effects of language familiarity and style (font vs. handwriting) on the word inversion effect

View Poster | Visit me in Gather.Town Egret Room on Monday 3:30 pm - 5:30 pm EDT

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Visual words and faces have very different properties, words being two-dimensional high-contrast binary stimuli and faces having complex mobile three-dimensional shapes. However, they are both visual stimuli for which humans have high expertise, and both activate similar cerebral networks (albeit with opposing hemispheric asymmetries), raising the possibility that they might share common perceptual mechanisms and effects. In the present study we examine word processing for one prominent effect described in face processing, the inversion effect. To capture the effect of expertise, we compared recognition for familiar and unfamiliar languages. To determine if stimulus variability played a role, we also compared computerized font and handwriting. We recruited two groups of 20 subjects, one fluent in Farsi and one in Punjabi, with neither familiar with the other language. Stimuli were single words of 5-7 letters in length, in one of 6 handwriting or 6 font styles, shown either upright or inverted. Subjects performed a three-alternative match-to-sample task, with 432 trials total. In addition, subjects performed the Cambridge Face Memory Test (CFMT). Subjects had higher accuracy and faster reaction times with the familiar language, and with computerized font. There was a word inversion effect for the familiar but not the unfamiliar script. The inversion effect for accuracy was almost twice as large for handwriting than computerized font. Performance with the inverted familiar language was still superior to that with the unfamiliar language, indicating that language familiarity still facilitates the processing of inverted stimuli. Word inversion effects did not correlate with face inversion effects on the CFMT. We conclude that experience does generate a word inversion effect, and that this effect is greater for less regular script, when reading requires generalization across natural variations in handwriting.

Poster Session F

Attention

Poster Session F > Attention > Poster F1

Behavioral and attentional coding of expected reward and risk

View Poster | Visit me in Gather.Town Osprey Room on Monday 8:00 pm - 10:00 pm EDT

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Uncertainty brings people not only the joys but also the pain of life. It is therefore fundamentally important for we humans to process uncertain information accurately and appropriately from daily investments to long-term return forecasts. Though risk processing during value-based decisions has been widely studied, whether the expected reward and reward risks could be processed automatically in a non-choice situation is still under-explored. Using a modified monetary incentive delay task (MIDT) in which mean reward and reward variance were parametrically manipulated and orthogonalized, we examined the behavioral and attentional coding of expected reward and risks at a more implicit level with strategical use of behavioral response time (RT) and simultaneous recording of eye movements. Behaviorally, we showed that RTs (n=90) varied as a function of mean reward but not reward variance, suggesting that reward magnitude is the main driver of response vigor. Moreover, fixation difference (n=68) between high and low value (total fixation duration/counts/ percentage and first fixation latency) was reduced with larger mean reward and smaller reward variance, providing the first attentional evidence coding for mean reward and reward variance automatically with similar visual patterns. Altogether, we provide behavioral and attentional evidence coding for expected utility and risks both similarly and differentially, irrespectively of whether the response is decision-related or not. Our findings may help to explain or predict pathological gambling or addictive behaviors based on atypical processing of reward and risks, i.e., augmented (reduced) weight of reward (or risks) during value-based decision-making. Our study may provide insights into behavioral intervention via attentional manipulation during value-based risky decisions.

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Poster Session F > Attention > Poster F3

Can attention break through the ensemble? Only with more time

View Poster | Visit me in Gather.Town Osprey Room on Monday 8:00 pm - 10:00 pm EDT

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Numerous studies have found that, although people can rapidly extract average emotions from face sequences through ensemble perception, they have poor representations of the individual faces in the sequence. This might be because the speed of the sequence exceeds the temporal processing capacity of individual faces. In this study, we manipulated the presentation duration of individual faces in a rapid serial visual presentation (RSVP) paradigm to investigate the transition from attention (to individual faces) to ensemble coding (of the entire sequence). Participants (N=31) were instructed to fixate on a central cross and view faces, morphed from sad to angry, in an RSVP stream. Each face appeared on screen for 167ms, 333ms, or 500ms, and the entire stream lasted for 2s. After a 1s interval, participants responded using a method of adjustment. In the “target” condition, participants attended to and reported the emotion of the ‘target’ face within the stream. In the “average” condition, they reported the average face of the stream. Multiple linear regression analysis was used to predict the response face based on the target face and the average face. In the “target” condition, with attention to the target and an increase in presentation duration, participants became more accurate at reporting the target face (slope $b=0.21$, $p<0.001$), and the average emotion contributed less to the emotion

decision (b=–0.20, p<0.001). However, in the "average" condition, although their response was significantly driven by the ensemble emotion (b=1.29, p<0.001), longer presentation duration did not alter performance. A control condition with inverted faces confirmed that these effects were not purely results of low-level feature processing. These results suggest that attention to a 'target' with sufficient processing time improved individual face perception and suppressed non-target faces, thus relying less on ensemble perception. Our study sheds light on the mechanisms of attention and ensemble perception.

Poster Session F > Attention > Poster F4

Disengaging from the forest versus the trees: The spatial extent of focused attention modulates the rate of attentional disengagement

View Poster | Visit me in Gather.Town Osprey Room on Monday 8:00 pm - 10:00 pm EDT

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Spatial attention can be flexibly changed to optimize visual processing. It can, for example, be moved from one location to another via a three-step process of disengaging, shifting, and engaging attention (attentional orienting) or it can be expanded or contracted in spatial extent to match the size of an attended object (attentional resizing). Although much is known individually about these aspects of attentional control, relatively little is known about how they interact with one another. In the present study we examined whether the spatial extent of the attentional focus modulates the efficiency of the first component of attentional orienting, the disengagement of attention. To test this, we used a small or large abrupt-onset central square to trigger the reflexive resizing of attention (Castiello & Umiltà, 1990) and a gap task to assess the rate of attentional disengagement (Mackeben & Nakayama, 1993). In the gap task, observers were cued to orient attention to a peripheral location. Prior to the onset of the orienting cue, the central fixation cross either disappeared (Gap condition) or remained visible (No-Gap condition). The removal of the fixation cross allowed attention to be disengaged early in the Gap condition, but not in the No-Gap condition. The task was to make a speeded discrimination response to a target. The rate of attentional disengagement can be estimated by subtracting average RT in the Gap condition from that in the No-Gap condition, and this RT difference is known as the gap effect. The results showed clearly that the magnitude of the gap effect was significantly greater when the focus of attention was small than when it was large (51.4 ms and 26.6 ms, respectively), indicating that the rate of disengagement was significantly slower when the focus of attention was small.

Acknowledgements: This research was supported in part by the Australian government through a Discovery Grant to LNJ.

Poster Session F > Attention > Poster F5

Exploring the neural correlates of stimulus-driven reorienting and stimulus evaluation

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Monday 8:00 pm - 10:00 pm EDT

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It has been well known that the right temporo-parietal junction (RTPJ), a part of the ventral attention network, plays a crucial role in reorienting attention. However, recently, several studies showed that the RTPJ was also involved in other cognitive processes than reorienting, such as an evaluative process, which refers to inferring or computing the behavioral significance/importance of the attended stimulus. Here, we investigated whether a region involved in reorienting of attention is also associated with evaluating the behavioral significance of attention-capturing stimuli. In an fMRI experiment, participants performed a modified Posner cueing task, in which four different arrow cues indicating four distinct locations were presented, followed by a target stimulus. Each cue predicted the target location to different extents; the cues predicted the target location with the probability of 80%, 20% (high-certainty cues), 60%, 40% (low-certainty cues). In each trial, participants made responses to a target, preceded by a cue stimulus. After four consecutive target responses, participants were required to infer how much each different cue predicts target location. We found that several fronto-parietal regions, frontal eye fields (FEF), intraparietal sulcus (IPS), and right temporo-parietal junction showed increased activity when the cued location and target location mismatched, evoking reorienting of attention. Notably, a dissociation was found from the cue inference activity; the RTPJ activity was greater for high-certainty cues,

whereas the FEF and IPS showed similar activity for these cues or greater activity for low-certainty cues. We suggest that the RTPJ activation increased under the high-certainty cue presentation because this region is associated with acquiring sensory information to evaluate the behavioral significance of a stimulus; with the high-certainty cues, the amount of evidence for inferring the cue predictability should be abundant. By contrast, other fronto-parietal regions seem to be sensitive to increased task demand or effort.

Poster Session F > Attention > Poster F6

The postdictive effect of choice reflects the modulation of attention on choice

View Poster | Visit me in Gather.Town Osprey Room on Monday 8:00 pm - 10:00 pm EDT

Yiling Zhou[1], Luo Chen[1], Mowei Shen[1], Hui Chen[1]; [1]Zhejiang University

Our conscious perception of the world is not an instantaneous, moment-by-moment construction. Rather, our perception of an event is influenced, over time, by information gained following the event: this is known as a postdictive effect. A recent study used a choice paradigm, where participants were asked to quickly choose from a set of options before a randomly selected option was made salient, and reported that postdictive effect could occur even in choice. The present study sought to test whether the striking postdictive effect of choice reflects the modulation of attention on choice, by directly and systematically manipulating attention in a similar choice paradigm in two experiments. Specifically, Experiment 1 revealed that the robust postdictive effect of choice was almost completely eliminated when attentional bias was removed. More importantly, Experiment 2 demonstrated that the postdictive effect of choice could be modulated by directly manipulating participants' attention with a spatial cue, in particular, when the cue appeared at short time delays. These results suggest that choice could be considerably postdictively influenced by attention and this effect was most pronounced within a short time window wherein decision-making was most likely in progress. The current study not only enables clarification of the mechanism of the newly discovered postdictive effect of choice, but also extends evidence of the modulation of attention on decision-making.

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Poster Session F > Attention > Poster F7

Temporal blank event facilitates sustained attention and attenuates the attentional blink

View Poster | Visit me in Gather.Town Osprey Room on Monday 8:00 pm - 10:00 pm EDT

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Although it is difficult for humans to sustain their attention to visual events, the temporal cueing of a critical event transiently elicits visual attention. However, it is still unknown whether the temporal cuing facilitates reorienting of attention between a pair of visual events, or not. Many studies show that it is difficult for human to reorient their visual attention from a previous target (T1) to a following target (T2) when the temporal lag between T1 and T2 is within about 500 ms (the attentional blink: AB). In this study, I investigated whether the temporal cueing attenuates the AB when observers had to pay attention sustainably to visual stimuli for about 14 minutes. For this purpose, I used a continuous rapid serial visual presentation (cRSVP), in which 200 pairs of T1 and T2 were embedded in a stream of thousands of distractors. Targets were arrows and distractors were random octagons. Each stimulus was presented for 150 ms. The observers were asked to detect the arrows and press the corresponding key as soon as possible. There were two experimental factors. The first factor was the temporal lag between T1 and T2 (1, 2, 5, or 10). The second factor was the temporal cueing of the onset of T1, which was given as a blank in the cRSPV stream. The conditions of the cueing factor were designed as a length of the blank (150 ms, 600 ms, or 0 ms). The results of the experiment showed that the AB was significantly attenuated in the condition in which the blank was 600 ms than the blank was 0 ms. These results suggest that a visually clear blank appeared during engagement in the sustained attention task can work as the temporal cueing of the visual events and facilitate to reorient visual attention.

Acknowledgements: A portion of this work was supported by JSPS KAKENHI Grant Number 20H01789.

Poster Session F > Attention > Poster F9

The temporal window of attention to self-generated stimuli

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Perceptual stimuli generated by one's actions (i.e., action-effects) attract attention more strongly than stimuli that occur independently of the action. Whether a stimulus is perceived as an action-effect or not is thought to depend on the temporal proximity of the action and stimulus. Given that, it is possible that the attentional boost to action-effects would have a specific temporal window. Thus, we assessed whether temporal contiguity between the action and effect modulates attention capture. We adopted a spatial orientating task in which a white central fixation and two white placeholders at the left and right locations were presented. We had two conditions; when the fixation turned red, participants in the action condition pressed a middle key while those in the non-action condition did not. Following this, one of two placeholders flashed in red for 50 ms as a cue, and after 50 ms a white circle as a target appeared inside either of the two placeholders. Thus, in the action condition, keypress caused the presentation of the cue while in the no-action condition, it did not. In the action condition, the interval between keypress and cue onset was 50, 750, or 3550 ms and in the no-action condition, the interval between the color change of the fixation and cue onset was 400, 1100, or 3900 ms (including 350 ms as an alternative of keypress time in the action condition). Participants quickly pressed either the left or right key depending on the target location. The results did not support the presence of a strict temporal window; action-effects captured more attention than external stimuli even more than three seconds after the action. This finding implies that the attention to action-effects does not result from time-sensitive sensorimotor processing, but reflects a more general process of action-effect monitoring.

Poster Session F > Attention > Poster F10

The visual attention at the hand-movement goal independent of the top-down attention

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[Introduction] Enhancement of visual perception near the goal of hand movements has suggested that there is a vision attention related to hand movements (hand-movement-goal, HMG attention). However, it is still an open question whether the HMG attention is a variation of the top-down attentional system. It is likely that the top-down attention is oriented to the goal of hand movement in everyday life conditions. To examine whether there is a specific attention process for HMG attention, we investigate the relationship with the top-down attention. [Method] In order to examine whether the HMG attention is a different process from the top-down attention, we conducted experiments to control the HMG attention and the top-down attention separately and also to estimate spatial distributions of the two types of attention using the Steady-State Visual Evoked Potential (SSVEP) of electroencephalogram. There were two attention-location conditions: in the same condition, a visual task was required at the location indicated as the HMG by a cue, and the visual task was required on the other side of the HMG around the fixation point in the opposite condition. There were also two hand-movement conditions: the hand-movement and hand-stationary conditions for each of the same and opposite conditions. The effect of hand movement can be obtained from the difference between the hand-movement and hand-stationary conditions for each of the same and opposite conditions. [Results] The SSVEP results confirmed the presence of facilitation in visual processing around the HMG during the preparation period of hand movement even when the top-down attention was directed to a different location. Estimated spatial distribution showed that the attention around the HMG was much narrower than that around the focus of the top-down attention spreading into locations. [Conclusion] We revealed that there is the HMG attention process that is independent of the top-down attention.

Poster Session F > Attention > Poster F11

Visual attention maximizes expected information gain in goal inference

View Poster | **Visit me in Gather.Town Osprey Room on Monday 8:00 pm - 10:00 pm EDT**

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Visual attention is a mechanism of information-seeking and uncertainty reduction. However, the fundamental question of how attention helps people reducing uncertainty is still poorly understood. This study aims to explore this issue by relating attention to the concept of Expected Information Gain (EIG) in information theory, which describes the expected value of uncertainty reduction. In three experiments, we designed a task to probe the relationship between EIG and attention: participants were asked to determine which of two targets was the goal of a moving agent. When the agent was at some locations in its path, observing the next move of the agent would have higher EIG (i.e., the observations were more likely to reduce uncertainty in participants' inference), while at other locations, the observations (with lower EIG) were less likely (even impossible) to reduce uncertainty. We used eye trackers to record participants' eye movements and pupil sizes to measure their attentional levels during the task. Experiment 1 showed that participants had greater pupil dilation as the levels of EIG increased. Moreover, participants' positions of fixations were less frequent to move away from the locations of the agent when EIG levels were higher. These results illustrate that the attentional levels increase with EIG levels. Experiment 2 added obstacles to agents' paths to break the distribution of EIG relative to spatial locations, finding participants' attentional levels still changed in parallel with EIG levels. In Experiment 3, the agent's paths were exactly the same as those in Experiment 1, but difference levels of EIG was made to vanish by manipulating the order that targets appeared. Consequently, the effects in Experiment 1 were greatly diminished. Combined, these results demonstrate that visual attention might be the process of resolving uncertainty as much as possible by maximizing the EIG.

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Poster Session F > Attention > Poster F12

Effects of exogenous and endogenous attention on perceived duration and stimulus onset detection

View Poster | **Visit me in Gather.Town Osprey Room on Monday 8:00 pm - 10:00 pm EDT**

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We examined how each of exogenous and endogenous attention affects perceived stimulus onset detection. Our preliminary study showed that perceived duration for a visual stimulus would be affected by exogenous attention, but not by endogenous attention (Katsumata & Ichikawa, APCV2019). In the present study, we combined target search task with temporal order judgment task in which we manipulated the spatial attention by pre-cuing method. We presented a white square as a target (1.0 x 1.0 arc deg) at 6 arc deg right or left of the center of screen. Exogenous attention was directed 100 ms before the onset of a target by presenting a cue in increasing luminance of a circular place holder (4.25 arc deg in diameter) from 22.9 cd/m2 to 90.0 cd/m2 while endogenous attention was directed 400 ms before the target onset by presenting a square or diamond place holder. We prepared the valid, invalid, and neutral conditions for the cuing. In each trial for both of exogenous and endogenous attentions, a cross (1.0 x 1.0 arc deg) was presented before or after the onset of the target at 1 arc deg above of the center of screen. SOA between the cross and target ranged from -94ms to 94 ms. Participants were asked to respond to the target stimulus as soon as possible, and then, judged which of target or cross appeared first. We found that the target detection in the valid condition was faster than those in the invalid and neutral conditions for both exogenous and endogenous attentions, and that exogenous attention prolonged the perceived duration although endogenous attention did not. These results indicate that effects of exogenous attention on duration perception would differ from those of endogenous attention. Bases of effects of exogenous and endogenous attentions on duration perception will be discussed.

Poster Session F > Attention > Poster F13

Horizontal vs. vertical spatial anisotropy of attentional bias toward negatively valenced words

View Poster | Visit me in Gather.Town Osprey Room on Monday 8:00 pm - 10:00 pm EDT

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Salient objects or events capture visual attention exogenously, and this biased allocation of attention can be modulated by contexts endogenously. Similarly, because this attentional bias is contingent on viewers' emotional state high trait-anxious population show attentional bias toward negatively valenced words and facial expressions. A literature review of the studies on attentional bias measured by dot-probe procedures in which participants respond to a probe preceded by a pair of negative and neutral words or faces suggests larger number of publications in horizontal relative to vertical word arrangements, whereas the pattern was opposite in negative-neutral face pairs. The present study examined the effect of spatial arrangements of negative vs. neutral word pairs on attentional bias in a healthy population, while introducing different levels of attentional demands by manipulating the type of probe task. A factorial design considering the spatial arrangement of words (vertical or horizontal) and the task (detection, localization, and discrimination) resulted in six between-participant comparisons. Participants viewed a word pair comprising a neutral and a negative word for 500 ms, followed by a target probe presentation at the location of either the neutral (incongruent condition) or the negative word (congruent condition). The scores for attentional bias toward negative stimuli, calculated as the mean difference in reaction time between the incongruent and congruent conditions of the localization task under the vertical arrangement, were significantly correlated with trait anxiety measured by the State–Trait Anxiety Inventory, whereas no such relationship was obtained under the horizontal arrangement. The spatial arrangement effect was weaker in the detection and identification tasks. The results suggest that attentional bias toward negative words can be modulated by the spatial arrangement of the stimuli and the attentional resources required for responses to the probe.

Poster Session F > Attention > Poster F14

Visibility of the prime is associated with both inhibition and facilitation in response priming.

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Response priming is a phenomenon that responses are faster when target and prime elicit the same response (congruent condition), compared with when they elicit the opposite responses (incongruent condition). The effect occurs even when the prime is invisible. However, the effect of visibility of the prime has not been verified. In addition, it was not clear whether the effect depends on the facilitation of response by the congruent prime or the inhibition by the incongruent prime. We found that the visibility of the prime measured by Perceptual Awareness Scale (PAS) affected both facilitation and inhibition (Morimoto & Makioka, VSS2020). The prime and the target were both arrows, and the participants responded to the direction of the target arrow with a joystick. In this study, we investigated whether the effect of visibility depends on the type of the stimuli and response; we used squares and diamonds for targets and primes. The participants responded whether the target was the square or the diamond by a mouse click. Thirty-three undergraduate student participated. Participants were told that two stimulus were presented in succession and the first stimuli (prime) might be invisible but the second stimuli (target) was always visible. They were instructed to response of the target as quickly and accurately as possible, and then to report PAS of the prime. Analysis by liner mixed model confirmed that the PAS of the prime affects the strength of the response priming independently of the SOA. The inhibitory effect by PAS of the incongruent prime and the facilitatory effect by PAS of the congruent prime were both observed. These results were consistent with the results of the experiment using arrow stimuli and the joystick response, confirming that the effects of facilitation and inhibition are independent of the type of the stimuli and response.

Poster Session F > Attention > Poster F15

Different effects of multisensory integration on three attention networks

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Multisensory integration affects attention in many ways. However, it is unclear whether multisensory integration has the

same effect on the three attention networks: alerting, orienting and executive control network (EC). This study aims to evaluate the effect of multisensory integration on three networks efficiency of attention. We manipulated the Flanker targets accompanied with/without the auditory stimuli in the ANT (Attention Network Test) paradigm. And used 4 (cue: no cue, center cue, double cue, spatial cue) × 3 (Flanker type: neutral, congruent, incongruent) × 2 (target modality type: visual and audiovisual) three within subject factors. In Experiment 1, present a meaningless pure tone stimulus on the left and right sides while the target stimulus appeared. The results showed that the processing efficiency of the alerting and orienting networks was lower when the target stimulus was accompanied by sound than when the target stimulus was not accompanied by sound, but there was no significant difference in the processing efficiency of the executive control networks. Experiment 2 was a pure sound that presented on the left or right (the sound appears in the same direction as the middle arrow). The results found that when the target stimulus was accompanied by sound, the effects executive control network was lower, and there are no significant difference in the effects alerting and orienting network. Results from the two experiments suggested that multisensory integration had different effects on three attention networks, this might be related to the spatial location of auditory stimuli. The interaction between multisensory integration and attention networks was discussed.

Acknowledgements: This study was supported in part by National Natural Science Foundation of China (31600882, XT).

Visual Search

Poster Session F > Visual Search > Poster F16

Attention Prioritization for a Friend's Target During Joint Visual Search

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Monday 8:00 pm - 10:00 pm EDT

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When object layouts are maintained in visual search, they can be learned and become visual cues for the target (i.e., contextual cueing effect); however, they do not facilitate search performance for an item that is a distractor (Võ & Wolfe, 2012). When pairs of participants search simultaneously, a friend's target may capture the other's attention. Therefore, in this study, we examined whether a friend's target could be identified faster in the learned context even as a distractor. Participants comprised 18 pairs of friends assigned to the joint-no-one's-target group and to the joint-friend's-target group, and 18 individuals assigned to the single-no-one's-target group. In every trial, one exemplar of each target category (i.e., bird, shoe, and tricycle) was shown among unique objects. In the repeated condition, all locations and identities were maintained. In the control condition, only the target locations and identities were maintained. In the learning phase, participants searched for one target category. In the subsequent transfer phase, the joint-no-one's-target group was instructed to search for the target that no one had searched for, while the joint-friend's-target group was instructed to search for the friend's target. The single-no-one's-target group searched for the target no one had searched for. The results revealed the contextual cueing effect in the learning phase and the transfer phase, with size being comparable across the groups. An exploratory analysis revealed that the greater the effect observed in the learning phase, the greater the effect they exhibited in the transfer phase only in the joint friend's-target group. This suggests that the learned contexts were utilized when searching for the friend's former target, and provides preliminary evidence that the friend's target is attended during a joint visual search.

Poster Session F > Visual Search > Poster F17

Distractor size matters: Distractors may, or may not, speed target-absent searches

View Poster | Visit me in Gather.Town Osprey Room on Monday 8:00 pm - 10:00 pm EDT

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Years of research have dissected the effects of salient distractors on visual search efficiency, typically finding that distractors slow visual search and increase error rates when detecting targets. Nonetheless, Moher (2020) recently demonstrated that the effects of salient distractors on visual search depend on target presence/absence. Specifically, when targets were present, Moher found that distractors slowed search speeds and increased error rates. However, when targets were absent, search speeds decreased, suggesting a strategy change in observers that lowered the quitting thresholds for target-absent visual search. This counterintuitive finding appears to depend on the salience of the

distractor. Replicating Moher (2020), we found that when the distractor was much larger than the other items, search speeds for target-absent trials were faster compared to when there was no distractor. In contrast, when a smaller but still salient distractor was used, search speeds for target-absent trials were slower compared to when the distractor was absent. Note that in both experiments the distractor was a different color than the other items. Potential reasons for these qualitatively divergent findings include the distance between the salient distractor and other search items or a shift in search strategy, which only emerges with very high salience distractors.

Acknowledgements: This work was supported by an NSERC Grant (2016-06359) awarded to Jay Pratt.

Poster Session F > Visual Search > Poster F18

Scene context limits processing to target-consistent regions without changing object processing rates in efficient search tasks

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Visual search in real-world scenes unfolds over two parallel pathways. One pathway processes scene information while the other processes object information. Scene context can limit the number of items that are searched through, resulting in reduced response times. The benefit of scene context has been studied extensively in inefficient search tasks. Recently, it was demonstrated that this benefit is also observed in efficient search tasks when search is sufficiently slow (e.g. when set size is large or when target-distractor similarity is high). In this study, we examined whether the mechanism behind the benefit of scene context in efficient search tasks. Eye movements were recorded while participants searched for a green turtle that could appear in the water, among black turtles that could appear anywhere on the search display. On half the trials, participants were given a 247ms preview of the scene background before the search items were presented. Response times were faster with preview, although there was no difference in search slopes. When the scene context was previewed, there was a greater proportion of initial saccades that were directed to the target-consistent region. Furthermore, this proportion increased as a function of initial saccade latency only when there was no preview, but not when there was a preview. Thus, when there was no preview, faster initial saccades were likely to be object-driven, while slower initial saccades were likely to be context-driven. On the other hand, when there was a preview, all initial saccades were likely to be context-driven. Lastly, the response times to distractors in the target-consistent region in the preview condition were similar to the response times to all distractors in the no-preview condition. Taken together, in efficient search tasks, scene context limits processing to target-consistent regions without changing the rate of evidence accumulation.

Poster Session F > Visual Search > Poster F19

Search Asymmetry Revisited: Search for Target with More Features than Distractors is Not Necessarily More Efficient

View Poster | Visit me in Gather.Town Osprey Room on Monday 8:00 pm - 10:00 pm EDT

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Search asymmetry is a change in search efficiency when target and distractor switch roles. Previous studies found a shallower slope and faster reaction times in searching for a long line among short lines than vice versa, suggesting that searching for targets with more features than distractors leads to better efficiency. However, studies showing search asymmetry mostly recruited participants from western countries, yet one study with Japanese participants found no search asymmetry (Ueda et al., 2018). We examine whether search asymmetry can be found with Taiwanese participants, and whether culture-related factors and target-distractor discriminability affect the results. Four series of experiments were conducted. Taiwanese participants were asked to search for a long-line target among short lines or the reverse with set sizes 3, 6, and 12 (Experiment 1). No search asymmetry was found since there was no difference in the slope of searching for a longer-line target than for a shorter-line target. Moreover, search asymmetry was not found when the line-search task was preceded by Chinese or English digit-word search to prime specific language experiences (Experiment 2A and 2B), or the Navon task as a priming task to induce holistic or analytic processing (Experiment 3A and 3B) even with different target-distractor discriminability (Experiment 4, difference in line-length of 0.2, 0.4, and 0.6

deg). Taken together, search asymmetry was not observed in all four experiments, indicating that the absence of search asymmetry was robust in Taiwanese participants. Besides the high discriminability condition, searching for a long line among short lines was slower than vice versa in all the conducted experiments, which was novel from previous Westerners' results. This study demonstrated the robustness of the lack of search asymmetry with Taiwanese participants, and provided an opportunity to consider the role of overall reaction time differences in visual search when search asymmetry is absent.

Poster Session F > Visual Search > Poster F20

Semantic contextual cueing effects depend on verbal working memory rather than spatial working memory

View Poster | Visit me in Gather.Town Osprey Room on Monday 8:00 pm - 10:00 pm EDT

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The visual world contains a variety of implicit rules that reveal the spatial or semantic relationships (contextual cues) between different objects. The facilitation effect of the efficiency in visual search induced by these contextual cues is termed as the contextual cueing effect. Previous studies have shown that spatial contextual cueing effect can be influenced by spatial working memory load. However, it remains unclear whether the semantic contextual cueing effect is also modulated by working memory load. Further, it is unclear whether different types of working memory (e.g., spatial or verbal working memory) load have the same effects on semantic contextual cueing effect. To clarify this issue, we examined whether semantic contextual cueing effects depend on any type of working memory resources (the common resource hypothesis) or only require the specific type of working memory resources (the specific resource hypothesis). In this study, we adopted a dual-task paradigm that combined a visual search task with a working memory task. Results showed that the semantic contextual cueing effect is influenced by verbal working memory load, but not by spatial working memory load. These findings indicated that specific contextual cueing effects only depend on specific types of working memory load, which supports the specific resource hypothesis.

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Poster Session F > Visual Search > Poster F21

Search efficiency in parallel search is not impacted (or only minimally so) by background complexity.

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Monday 8:00 pm - 10:00 pm EDT

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In efficient visual search tasks, response times increase logarithmically as a function of set size. This reflects an evidence accumulation process. The accumulation rate is indexed by the slope of this function. The less similar are the target and the item, the faster is the accumulation rate, the flatter is the slope. Here, we examined whether background complexity impacts search efficiency in parallel search in real-world scenes. In Experiment 1, a relatively unstructured background was studied. Observers searched for a green turtle presented against one of three unstructured backgrounds which varied in complexity: a solid-colored background (lowest complexity), a beach, and a phase-scrambled beach background (highest complexity). For half the participants, the distractors were yellow turtles (high target-distractor similarity). For the other half, the distractors were black turtles (low target-distractor similarity). Although background did not affect accumulation rates in the low-similarity condition, in the high-similarity condition, a significant but small reduction in accumulation rates was observed as background complexity increased. The magnitude of this effect on the log slope was relatively small (an increase of about 12.7%). In Experiment 2, a more structured background scene (a bedroom) was studied. Observers searched for a teddy bear presented against one of three backgrounds: the bedroom, a phase-scrambled version of the bedroom, and an upside-down version of the bedroom. For half the participants, the distractors were red dolls (high-similarity). For the other half, the distractors were white reindeers (low-

similarity). In this experiment, the search slopes did not vary as a function of background. Overall, we concluded that background complexity does not have a meaningful effect on search efficiency, and when effects are observed, they tend to be small in magnitude.

Acknowledgements: This material is based upon work supported by the National Science Foundation under Grant No BCS1921735 to SB.

Possibility of predicting target position immediately by anchor object

View Poster | Visit me in Gather.Town Osprey Room on Monday 8:00 pm - 10:00 pm EDT

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Visual search in naturalistic scenes has a hypothesis of anchor object. In context consistent scenes, it helps us to predict the locations of other objects and improves the perceptive speed. Previous study (Boettcher et al., 2018) verified the effects of anchor object by the perceptual distance between consistent and inconsistent scenes during visual search. Furthermore, there is a possibility that anchor object affects us not only during searching but also at an early stage of it. Therefore, we proposed a hypothesis that predicts the location of other object immediately after perceiving anchor object. In our experiment, 20 images were presented to 15 participants (2 female, our lab members) for 100ms each. We made the image dataset, and we selected "the sink" or "the table (desk)" as anchor object in the image. We selected a small object as “the target”, which was close to the anchor object. We think this may be affected by the anchor object. We asked participants presence or absence of anchor object by multiple-choice question, and the position of the target using the mouse, every images. Accuracy in both cases were compared by the distances between predictive and correct points. The results showed that participants selected anchor object 238 times, didn't select 62 times. Mean distance between predicted position and correct position was M = 335px, 95% CI [301,369] in selected case, the other case was M = 474px, 95% CI [392,555]. In addition, we used Welch's t-test to compare two groups ($t(83) = 3.12, p = 0.00248$, Cohen’s $d = 0.503$). According to the results, the case of perceiving anchor object has tendency to predict better than the other case. This suggests that the position of the target is predicted immediately when we perceive anchor object.

Target-absent visual search reveals distinctiveness computations in the brain

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Monday 8:00 pm - 10:00 pm EDT

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We all know that finding a target is easy if the distractors are dissimilar. However, why are target-absent searches systematic? More specifically, what property of the distractor makes some target-absent searches easy? Surprisingly there have not been any attempts to answer this question. Here we set out to investigate this question using a combination of behavioral and fMRI experiments in humans. In Experiment 1, subjects had to view a search array and indicate whether any oddball target is present or absent. Target absent times were highly systematic, as evidenced by a strong split-half correlation across subjects ($r = 0.75$, $p < 0.0005$). We hypothesized that the target-absent search time might depend on how distinctive an object is compared to other objects. We measured the pairwise dissimilarity between all pairs of images in Experiment 2. For each object, we measured its distinctiveness as its average distance from all other objects in the experiment. This quantity, derived from target-present search times, was strongly predictive of the target-absent search time ($r = -0.77$, $p < 0.0005$). In Experiment 3, we measured brain activations using fMRI while subjects performed a visual search task to investigate the neural correlates of distinctiveness. We hypothesized that if a brain region is computing distinctiveness of an object then its activations during target-absent search should predict the distractor's distinctiveness. On each trial, subjects had to indicate whether an oddball target was present or not using a key press. Consistent with previous work, neural representations in the lateral occipital (LO) region matched best with visual search behavior ($r = 0.67$, $p<0.00005$). Importantly, neural activations in a region anterior to LO predicted distinctiveness during target-absent searches ($r = -0.53$, $p < 0.005$). Taken together our results show that distinctiveness computations in higher visual areas predict systematic variations in target-absent search times.

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Poster Session F > Visual Search > Poster F24

Category Learning of Medical Images: How does Comparison Help?

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Monday 8:00 pm - 10:00 pm EDT

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Physicians need to observe dozens of medical images every day, which is a crucial step in medical diagnosis. It is thus essential to investigate how medical students and interns can learn to diagnose by medical images more efficiently. In the current study, we combined eye-tracking technology to explore the following three specific questions: (1) the effect of comparison learning on performances in medical image diagnosis tasks, (2) the interaction between comparison learning and medical knowledge, and (3) the persistence of comparison learning. In Experiment 1, we found that participants in the comparison-learning goup had better behavior performances, fewer fixation counts, and shorter fixation duration after comparison learning, compared with participants in the non-comparison-learning group. In Experiment 2, we further uncovered the promotion effect of medical knowledge on category learning in medical imaging. In Experiment 3, we found that visual perceptual comparison learning still benefited diagnosis in a delayed test, indicating its persistent effect. The above results uncovered the long-lasting effect of comparison learning in medical diagnosis and advocated the use of comparison learning in the teaching practice of medical students.

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Visual Memory

Poster Session F > Visual Memory > Poster F41

Visual short-term memory contents bias eye-specific attention

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The history of attentional deployment induces attentional bias. In the current study, we investigated whether eye-specific attentional selection within visual short-term memory (VSTM) can bias attention in an eye-specific manner. Participants encoded two Gabor patches presented to the left and right visual field of each eye using a binocular rivalry paradigm. During the retention period, a retro cue appeared to indicate the to-be-tested item. After selecting the item within VSTM, in a subset of trials, participants were required to respond to a probe that could be presented to either left or right eye. Though the participants were unaware of the eye-of-origin of the probe, their response was significantly faster when the probe appeared to the same eye where the previously selected VSTM item was presented to. This result implies that attention is biased involuntary in an eye-specific manner during VSTM retention. The current finding further suggests that VSTM retention might recruit the visual pathway where selective attention was required during the encoding period.

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Poster Session F > Visual Memory > Poster F42

Trading Capacity for Precision in Working Memory: Reviving the Effect of Negative Emotion on Working Memory

View Poster | Visit me in Gather.Town Manatee Room on Monday 8:00 pm - 10:00 pm EDT

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Working memory (WM) stores and manipulates a limited set of information for ongoing tasks, playing a critical role in our daily life. How the emotion affects WM has long been the interest of researchers. Recently it has been debated about

whether negative emotion boosts the precision with which information being stored in WM: While initial studies supported this view, recent studies did not find positive evidence. The current study addressed this issue by using a color-recalling WM task at two different universities, which had different economic statuses. Participants were first presented a negative or neutral picture, then performed the WM task. In two experiments, in line with recent studies we found that the negative emotion did not affect the WM capacity or precision regardless of economic statuses. However, we consistently found that the precision difference between the two emotional conditions was negatively correlated with the capacity difference between the two emotional states: The higher degree the negative emotion impaired WM capacity, the larger degree the negative emotion boots WM precision. This finding suggests that the negative emotion indeed induces a trade-off between WM capacity and precision, and reconciles previous contradictory results.

Poster Session F > Visual Memory > Poster F43

Retaining Quantitative-dimension Binding in Working Memory: A Passive Process

View Poster | Visit me in Gather.Town Manatee Room on Monday 8:00 pm - 10:00 pm EDT

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The binding problem is one of the core issues in working memory (WM), and has been explored extensively. Recent studies suggested that retaining bindings in WM requires more object-based attention than retaining constituent single dimensions. While human beings have evolved unique capabilities of quantity processing, no study so far has explored the attentional mechanism of retaining quantitative-dimension bindings in WM, which may be endowed with a unique attention mechanism. The current study aimed to explore whether extra object-based attention is required in retaining quantitative-dimension bindings in WM via a dual-task paradigm. Participants were required to memorize feature dimensions or the bindings between two dimensions in a change detection task. Critically, a secondary transparent motion task was added to compete for object-based attention with the memory array. If object-based attention plays a pivotal role in retaining bindings in WM, the secondary task would lead to a larger impairment for bindings relative to constitute dimensions (selective binding impairment). Line's length and circle's area were used as the representatives of quantitative-dimensions, while colors and locations were used as qualitative-dimensions. We found that the secondary task did not lead to a selective binding impairment for bindings containing quantitative-dimensions (Experiments 1 and 5 length-color, Experiment 2 length-location, and Experiment 3 area-color), which is against the bindings without quantitative-dimensions (Experiment 4 color-location; as well as ample previous studies). The results suggested that retaining quantitative-dimension bindings in WM is a passive process, and does not require extra object-based attention relative to the constituent single dimensions.

Poster Session F > Visual Memory > Poster F44

How does working memory work? The manipulation unit of visual working memory

View Poster | Visit me in Gather.Town Manatee Room on Monday 8:00 pm - 10:00 pm EDT

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What is the manipulation unit of visual working memory (VWM)? This is a key question to understand how the human mind updates the information absent in view to adapt to the ever-changing environment. We proposed two hypotheses: (a) the object-based hypothesis expects longer manipulating times when more objects are involved in manipulation, while (b) the Boolean-map-based hypothesis expects longer manipulating times when more Boolean maps are involved in manipulation. In Experiments 1 to 3, participants were asked to move, search, or dye a subset of stimuli (different numbers of orientations/objects, but all in one Boolean map) in VWM and then finish a change detection task. The results support the object-based hypothesis that participants' manipulating times differed when manipulating different numbers of orientations although there was only one Boolean map all the time. In Experiment 4, two different colors linked together were presented on the same object (different Boolean maps) while two same colors were presented on different objects (same Boolean map). Participants were asked to dye a subset of stimuli into two different colors in VWM. The results showed that manipulating colors from one object (two different Boolean maps) was faster than that from two different objects (one Boolean map), supporting the object-based hypothesis. In conclusion, we adopted four novel manipulating tasks and found that objects are the elementary manipulation unit of VWM, instead of Boolean maps.

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Poster Session F > Visual Memory > Poster F45

Memory superiority for interactive biological motion in working memory

View Poster | Visit me in Gather.Town Manatee Room on Monday 8:00 pm - 10:00 pm EDT

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Remembering interactive actions is crucial for guiding behaviors of human beings in society. In this study, we investigated how the significance of interactive biological motion (BM) information is embodied in working memory by asking whether there is a memory superiority for interactive BM in working memory, as well as the underlying mechanism. We present both interactive and non-interactive BM pairs, while participants were only asked to memorize the individual actions and complete a change detection task. The results uncovered a significantly higher memory accuracy for interactive BM pairs than that for the non-interactive BM pairs, no matter presenting the two BM pairs simultaneously (Experiment 1) or present two pairs one after another (Experiment 2). Followed eye-tracking studies found that participants devoted more attention resources to the non-interactive BM in the encoding and maintenance phase in a compensating manner. Taking together, the current study shows that interactive BM can be encoded and stored in working memory economically, exhibiting a memory superiority.

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Poster Session F > Visual Memory > Poster F47

Probabilistic working memory representations in visual cortex

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Models of working memory (WM) suggest that individual memories are maintained as complex distributions over feature space that encode both the memory and the memory uncertainty. However, there is little empirical evidence to support this idea, and contemporary research (either implicitly or explicitly) assumes that WM representations encode discrete points in feature space. To investigate whether WM representations are probabilistic, we asked whether memory uncertainty measured using a betting paradigm was reflected in neural measures of WM representations measured with fMRI. Subjects memorized the direction of a dot-motion stimulus. After a delay, instead of making a single report about the direction of motion that they were maintaining, subjects placed 6 “bets” about the memorized direction, resulting in a distribution over 360° direction space that reflected subjects’ memory uncertainty. We used a linear classifier to identify WM representations in visual cortex. Instead of simply decoding the maintained direction of motion (i.e., the direction indicated by subjects’ first bet), we examined whether the classifier evidence captured the complexity of the memory uncertainty. Subjects’ distributions were often shifted either clockwise or counter-clockwise from the first response. Does this aspect of the uncertainty distribution reflect meaningful information above and beyond the initial response? If so, classifier evidence should be greater on trials where the bet distribution was shifted towards the nearest class than on trials where the bet distribution was shifted away from the nearest class. Indeed, classifier evidence was significantly greater when the distribution was shifted towards the nearest class, despite these trials having first bets that were further away from the nearest direction class. These results demonstrate that visual cortex stores rich and detailed information about WM memoranda that extend beyond a simple point estimate, thus lending empirical support for the notion that WM representations are stored as probability distributions.

Poster Session F > Visual Memory > Poster F48

Selectively maintaining object features within visual working memory

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Visual working memory (VWM) temporarily stores and manipulates a very limited set of visual information. In the past 15 years, the majority of the current VWM studies have focused on its storage mechanisms. However, few studies has been involved in the ‘working’ characteristic of VWM, one of which is selective maintenance. Recent researchers have attempted to explore the underlying mechanisms of VWM in selectively maintaining objects presented at distinct locations. However, the selective maintenance mechanisms over the constituent features of object have not been explored before. The current project aimed at exploring this issue. Particularly, according to the interactive model of perception and VWM, we hypothesized that the selective maintenance of object-feature depends on the characteristics of object: There are distinct mechanisms on selective maintenance between object containing fine-grained information (colored-polygons) and object composed of highly-discriminable features (colored-shapes). We tested this hypothesis by adopting the retro-cue paradigm combined with visual search task. In our study, an object composed two features was initially memorized. During the maintenance phase, we presented a retro-cue to inform participants to selectively retain one feature and drop another, and then require participants to complete a visual search task. If the selective maintenance of object-feature exists, the search time would not be prolonged significantly when the ignored feature appears as distracter. In line with our prediction, we found that the ignored features could capture attention in visual search task when colored-shapes were presented as memory stimuli (Experiment 1), while the ignored polygon could not when colored-ploygons were presented as memory stimuli (Experiment 2), suggesting that selective maintenance could occur for the object composed of fine-grained features but could not occur for the object composed of highly-discriminable information. This research reveals there exists dissociable mechanism when VWM selectively maintaining object features.

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Poster Session F > Visual Memory > Poster F49

Biological Movement is Stored Independently from Body Posture in Working Memory

View Poster | Play Video | Visit me in Gather.Town Manatee Room on Monday 8:00 pm - 10:00 pm EDT

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There are two basic forms of information as to human behavior in our daily life: dynamic biological movement (BM) and static body posture (BP). Recent neuroimaging studies implied that mirror neurons involve in the processing of both BM and BP. It is thus possible that BM and BP share the same storage buffer in working memory (same buffer hypothesis). However, BM and BP might be distinct types of representation in the cognitive system, with distinct storage buffers in working memory (distinct buffer hypothesis). We differentiated the two hypotheses in two experiments. We required participants to memorize a set of BM and BP simultaneously, and fixed the memory load of one category (e.g., 3 instances of BP; fixed category) while manipulating the load of the other (e.g., 0 - 3 instances of BM; flexible category). If BM and BP share one storage buffer, then the memory performance of fixed category would be modulated by the memory load of flexible category; otherwise, it would not be affected. BM and BP was set as the fixed category in Experiment 1 and 2, respectively. The two experiments consistently found that the memory performance of fixed category was not modulated by the memory load of flexible category. These results suggest that BM and BP are stored independently in working memory, and there might be distinct representations and rehearsal mechanisms for BM and BP in working memory.

Poster Session F > Visual Memory > Poster F50

A gradual transition from veridical to categorical representations along the visual hierarchy for memory but not perception.

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The ability to stably maintain visual information over brief delays is central to many cognitive tasks. A potential neural mechanism to achieve visual working memory stability is to maintain multiple concurrent representations at various levels of abstraction and cortical loci. Recent work has shown “sensory-like” mnemonic representations in early visual cortex, while the same mnemonic information is represented in a transformed format in the intraparietal sulcus. As an explicit test of mnemonic code transformations along the visual hierarchy, we quantitatively modeled the progression of veridical-to-categorical orientation representation via a reanalysis of an existing fMRI dataset. Six participants performed both a visual perception (rare target detection) and a visual working memory task (delayed estimation). fMRI activation patterns in different retinotopic regions of interest were sorted into bins based on the orientation shown or remembered. For each task and retinotopic area, the representational similarity of activation patterns in each orientation bin was determined based on Euclidean distances. We compared the resulting confusion matrices with two explicit models: The veridical model assumes that each orientation is most similar to adjacent orientations, and increasingly dissimilar to more distant orientations. The categorical model assumes that orientations are coded in quadrants relative to cardinal axes, so between either “twelve-to-three” or “three-to-six” o’clock. For the perceptual task, the veridical model explained the data well in all retinotopic areas, while the categorical model did not. While the veridical model also did well in the working memory task, the categorical model gradually gained explanatory strength for increasingly anterior retinotopically defined areas. These findings suggest that once visual representations are no longer tethered to sensory inputs, there is a gradual progression from veridical to more categorical mnemonic formats along the visual hierarchy.

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Poster Session F > Visual Memory > Poster F51

Involuntary and voluntary processes compete for entering focus of attention of working memory

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Representations in focus of attention (FOA) of working memory (WM) have the highest activation state and processing privilege. There are two distinct ways for representations entering FOA: Involuntary and voluntary processes. While extensive WM studies had investigated the two processes, the two processes have been largely examined separately. There are situations that the two processes co-exist but have distinct targets in a task, resulting in FOA competition between the two processes. It remains unclear the underlying competition mechanism. We examined this issue by using a color singleton cue in memory array to evoke an involuntary process and a retro-cue in the WM maintenance phase to initiate a voluntary process. We investigated whether and how the singleton benefit was modulated by the retro-cue when they had distinct targets. In three experiments, we consistently found that the item with a stronger cue enters FOA: Singleton benefit is erased by a strong retro-cue but not a weak retro-cue. These results together suggest that involuntary and voluntary processes compete for a limited capacity of FOA, and the stronger process will win the competition in guiding an item into FOA.

Poster Session F > Visual Memory > Poster F52

Continuous spatial perception is organized via cartesian coordinate over time: evidence from ‘serial dependence effect’

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Human perception is imperfect. For instance, subjects’ perception of a target’s location in the current trial would be

systematically biased toward that in previous trial, i.e., ‘serial dependence effect (SDE)’ in spatial perception. Meanwhile, instead of presenting stimulus in a continuous two- or three-dimensional space as we typically experience in daily life, previous studies have limited the stimulus presentation on a certain circle, leaving the SDE in a continuous spatial context largely unknown. Here, we performed three experiments to examine the SDE in two-dimensional, continuous space and the underlying spatial organization principle. In each trial, participants were presented with a stimulus at specific location and needed to reproduce its location later for all three experiments varying in spatial context (distribution within round area or square area), task difficulty (with or without an irrelevant task), stimulus shape (dot or bar), and experimental environment (online or offline). We used Cartesian (x and y) and Polar (ρ and ϕ) coordinates to characterize SDE: the response error in a certain dimension as a function of distance between the stimuli locations in current trials and those in previous trials. First, for the SDE in ϕ dimension, we found that the SDE was best explained by the DoG (derivative of gaussian) function, similar to previous findings for other circular variables, e.g., location on a circle, orientation, etc. In contrast, the SDE in other dimensions (x, y, ρ) showed a linear function. After combing two individual dimensions into coordinates, we found Cartesian coordinates outperformed Polar coordinates in explaining the SDE consistently among all three experiments. Taken together, by assessing the SDE of spatial location in a continuous space, we find that Cartesian coordinates (horizontal and vertical axes) instead of Polar coordinates (diagonal axes) are employed to organize continuous spatial information over time.

Poster Session F > Visual Memory > Poster F53

The role of anodal transcranial direct current stimulation (tDCS) in the consolidation of visual perceptual learning is mediated by the wake/sleep cycle

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Visual skills can be improved substantially after extensive training, a phenomenon called visual perceptual learning (VPL). It has been documented that both sleep and noninvasive brain stimulation (NIBS) (e.g., transcranial direct current stimulation (tDCS)) can enhance learning and memory, especially during consolidation, a vital stage of transforming fragile memory engram into long-term storage. However, how sleep and NIBS interact during VPL consolidation remains unclear. In this study, we investigated this issue using a 2 (25 minutes of 2 mA anodal tDCS vs. sham stimulation) × 2 (morning-evening condition vs. evening-morning condition) between-subject design. Four groups of subjects were randomly assigned to one of the four experimental conditions and were trained with an orientation discrimination task. TDCS was applied over the visual cortex immediately after the end of the training session. In the morning-evening condition, subjects completed a training session in the morning and a test session in the evening of the same day. They kept awake during the daytime. We found that, for the tDCS group, compared with the morning training session, the orientation discrimination threshold in the evening test session decreased significantly. No such an effect was found in the sham stimulation group. In the evening-morning condition, subjects completed a training session in the evening and a test session in the next morning. They had a night sleep at home. After sleep, there was a significant decrease in discrimination threshold for the sham stimulation group, whereas the discrimination threshold increased significantly for the tDCS group. Our results demonstrated that VPL consolidation was sleep-dependent and the effect of anodal tDCS on VPL consolidation was mediated by the wake/sleep cycle, implying that the homeostatic plasticity may play a critical role in VPL consolidation during sleep.

Poster Session F > Visual Memory > Poster F54

The fate of surface features in moving object when crossing a tunnel

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Object-based encoding (OBE) is a critical information processing manner in visual working memory (VWM). It has been

demonstrated that in the OBE, together with relevant feature, the irrelevant features are also selected into VWM. However, all previous studies used static objects (e.g., colored shapes) as the stimuli of interest. Our living environment is dynamic, and ample studies have revealed remarkable differences in the processing mechanisms between static and dynamic situations. Consequently, it remains unclear whether the OBE exists in a dynamic situation. Here we explored this issue by constructing a dynamic scenario, which simulated a real moving scene to explore the fate of moving objects' surface features. To ensure the involvement of VWM, we inserted a tunnel in the scenario. Colored balls moved from one side of the tunnel to the other side. We asked the participants to report whether the direction of moving ball changed after it moving through the tunnel. Importantly, we also manipulated the identity of color: in 50% of trials the surface feature colors were changed into new ones. Both behavioral and EEG data were recorded. We found that the change of surface feature significantly affected the behavioral performance, and elicited a more negative posterior N2. These results suggest that the surface feature of moving objects can be automatically stored in VWM, and the OBE occurs in a dynamic situation.

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Scene Perception

Poster Session F > Scene Perception > Poster F56

The role of high-order statistics in evoking perceptual priming effect on rapid scene categorization

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Previous studies have shown that higher-order statistics underlie observers' performance in animal detection task (Banno & Saiki, 2015), and is more efficient than second-order statistics in masking scene gist perception (Loschky, Sethi, & Pydimarri, 2010), indicating that higher-order statistics might play an important role in scene recognition. In the current study, we examined if high-order statistics could evoke perceptual priming effects on rapid scene recognition. For this purpose, it is necessary to extract higher-order statistics from intact scene images without extracting information such as the contour of objects and the overall spatial layout of the scene that could lead to conceptual priming. The algorithm suggested by Portilla and Simoncelli (2000) could meet this need by preserving higher-order statistics of images while disorganizing global configuration at the same time. Thus, we synthesized texture images using Portilla and Simoncelli's (2000) algorithm to preserve higher-order statistics of scenes while making them unrecognizable for their gist. Two experiments were conducted using the paradigm based on previous studies: participants were first presented with eight primes followed by an intact target scene, and were instructed to answer the basic category of the target scene in a four-alternative forced choice task. Priming level (all primes belonged to the same basic category vs. all primes belonged to the same superordinate category) and prime-target category congruency (congruent vs. incongruent) was manipulated. Experiment 1 used intact images as primes (conceptual priming and perceptual priming), while experiment 2 used texture images synthesized based on the primes used in experiment 1 (perceptual priming). We found facilitation from primes on rapid scene recognition under the prime-target congruent condition of experiment 1, while no robust influence from prime-target congruency was found in experiment 2. The current results suggest that higher-order statistics itself is not sufficient to evoke category-specific perceptual priming effect in rapid scene categorization.

Poster Session F > Scene Perception > Poster F58

Determinants of visual discrimination, visual preference and perceived complexity of synthetic images varying in natural scene statistics

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Introduction: Natural images are extraordinarily rich source of redundant information and the human visual system has evolved to exploit this redundancy. One such property is scale invariance reflected in 1/f amplitude spectrum of natural scenes. While a number of both psychophysical and physiological studies have confirmed the visual system's tuning to 1/f scene statistics, our understanding of what aspects of variations in the amplitude spectrum are responsible for this tuning is still relatively incomplete. In this study we compare photometric (edge amplitude) versus geometric (edge density) properties of synthetic filtered images in driving visual sensitivity, perceived complexity and preference . Methods: We measured discrimination sensitivity, perceived complexity and visual preferences using 3 sets of images; greyscale (GS), thresholded (TH) and edges only (ED) all of which spanned a range of α (0.25, 0.75, 1.25, 1.75 & 2.25). Between these sets photometric structure varied while geometric properties remained stable. Thresholds for discriminating increases and decreases in α were measured by a 4AFC at each of the five reference levels (n=45), while visual preference (n=45) and visual complexity (n=40) were determined via 2AFC paired comparison procedure. The perceived complexity measurements were conducted using a larger range of image sets (GS, TH, ED, mountain cross-section & 3D terrain) and an expanded range α (0.5- 2.5). Results & Conclusion: Both discrimination sensitivity and visual preference peaked for α ~ 1.25, confirming previous findings. Importantly, they were nearly identical for the GS, TH and ED images. Perceived complexity increased with α and similar to visual preferences scaled comparably across the different image types. The study findings provide converging evidence that visual discrimination sensitivity, visual preferences and perceived complexity are more strongly determined by the geometric structure of an image relative to their full photometric structure.

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Ensemble coding of temporally distributed elements eliminates irrelevant stimuli of salient size

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Ensemble coding is a mode of our visual system in which summary statistics like average size can be extracted from a group of multiple objects. Although ensemble coding is basically very accurate, it becomes less accurate when irrelevant stimuli are mixed in with the group of interest. A previous study indicated that when an array of variously sized circles of two colors, relevant and irrelevant ones, were presented simultaneously, the perceived average size of the relevant stimuli was affected by the average of the irrelevant stimuli, indicating that it is hard to ignore salient stimuli (Nakada & Murakami, VSS2020). In the present study, we presented variously sized circles of two colors sequentially at the same location and investigated whether observers could pick up only the relevant stimuli to extract their average size. We used the "rapid serial visual presentation (RSVP)" method to present the colored circles. Observers, who were to focus only the blue circles, were presented with two groups of circles in sequence. The first group also contained green circles, whose average was chosen from three values (less than, equal to, and greater than the average of the blue circles). They would differently affect the perceived average size of the blue circles if ensemble coding was affected by irrelevant stimuli. However, when the average of the green circles was greater than that of the blue circles, the perceived average size did not change. On the other hand, when the average of the green circles was less than or equal to that of the blue circles, the perceived average size became smaller. Ensemble coding is known to extract the salient elements of the group, but we found that in successive presentation, irrelevant stimuli of larger sizes are eliminated, although it is still hard to completely ignore other irrelevant stimuli.

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Boundary extension and contraction are predicted by the natural statistics of images

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Visual memory is subject to systematic errors. By understanding how these errors come about, we can uncover fundamental processes that shape the visual representations of human memory. One of the most robust and perplexing

types of memory error is boundary transformation, in which observers reliably misremember a scene as either farther (boundary extension) or closer (boundary contraction) than it actually was. What drives these boundary-transformation errors? The normalization theory proposes that scene memories are biased toward canonical views. For example, if our view of a scene is unusually close, our memory will be biased toward a farther and more typical view, showing boundary extension. This theory raises a central question that has yet to be addressed: Can boundary-transformation effects be predicted from the natural statistics of observed viewpoints in real-world scenes? Here we leveraged a large sample of scenes with ground-truth depth maps to quantify the natural statistics of viewing distance. We characterized the distributions of mean depth values in natural images for multiple categories of indoor scenes (e.g., kitchen, office) and used these as estimates of viewing distance. We then performed a series of behavioral experiments to determine if remembered scene boundaries transform toward the most frequent depth for different categories. Based on experiments involving both real-world scenes and well-controlled virtual environments, we found that the natural statistics of scene depth are predictive of the direction and magnitude of boundary-transformation effects. Furthermore, we found that an analogous phenomenon exists for images of individual objects—remembered objects are transformed toward their average sizes in real-world images. Together, these findings demonstrate that the natural statistics of images are predictive of memory errors for image boundaries, and they suggest a normalization process by which memories of scenes and objects are biased toward canonical views.

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Effective CNN-based Image Dehazing for UAV Deep Visual Odometry

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With advancement in Unmanned Aerial Vehicle systems (UAVs), UAVs can perform navigation for aerial photography and environmental inspections in areas deemed unreachable or dangerous for humans. Compared to inertial-based or GPS-based navigation, visual-based navigation via visual odometry has become a popular alternative as the former incurs drift errors while the latter GPS-signal is not available in some locations. However, feature extraction algorithms in odometry are heavily dependent on visibility of the features and it does not work well in foggy or hazy environments. To tackle this problem, we approached image dehazing algorithms to increase the visibility before implementing odometry. In this work, we introduce MLCA-DehazeVO, where dehazing is performed using a network inspired from light convolutional autoencoder (Pavan et al, 2020). The network comprises of an encoder to extract the latent representation of the hazy images, and a decoder that reconstruct the dehazed image to closely match the clear images. For odometry procedures, feature is extracted using Convolutional Neural Network (CNN) and Long-Short Term Memory is deployed for sequential feature relations analysis. We experimented our methods using the Montefiore Institute Dataset of Aerial Images and Records (MIDAIR) on 5 different trajectories that provides both clear and foggy paired synthetic sequential images with ground truth trajectories and pose data for comparison. Our approach is evaluated and shown to outperform prior-based dehazing methods (e.g. Dark Channel Prior) and performed favourably against other learning-based dehazing methods (e.g. DehazeNet) (PSNR(prior)<60.00, SSIM(prior)<0.400, PSNR(learning)>60.00, SSIM(learning)>0.400 in general, with highest PSNR(MLCA) = 67.50 and highest SSIM(MLCA) = 0.747), with the deep VO approach outperforming traditional VO methods with respect to lower relative translational error t_rel and rotational error r_rel. Our model improved the algorithmic architecture in dehazing and VO with high accuracy, thus shedding light on autonomous navigation under adverse environment and atmosphere.

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Perception and Action

Poster Session F > Perception and Action > Poster F62

Postural adjustment as a function of the spatial frame tilt.

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Humans use multisensory information to maintain balance. Especially, vision plays an important role. A tilted visual frame can induce postural sway toward the frame tilt (Isableu et al., 1997, Exp. Brain Res), suggesting the influence of visually estimated direction of gravity on postural control. In this study, we systematically changed the frame tilt and measured the postural adjustment and subjective visual vertical. Healthy young adults participated in the postural measurement and the rod adjustment task. In the postural experiment, standing participants observed an 8 m × 8 m × 20 m virtual room for 10 s through a head mounted display (HMD). The room tilted between -42° and 42° around the sagittal axis. Participants' head movement was collected by the HMD's tracking system. Head displacements were averaged for the mediolateral head positions relative to the initial position for each trial. In the rod adjustment task, the same visual stimuli were presented as the postural experiment, while seated participants were asked to manually adjust a rod at the room center to be gravitationally vertical. Subjective visual verticals were defined as the angular errors of the adjusted rod from the gravitational vertical. Consistent with the previous reports, we found biased head displacement toward the room tilt. The amount of the head displacement changed non-linearly as a function of the room tilt. The head displacement was the highest around the 20° room tilt, returning to the baseline as the room tilt further increased. The subjective visual vertical in the rod task showed consistent changes with the head displacement, with the maximum bias at around 20° room tilt. The weighted vector sum model (Mittelstaedt, 1983), can account for both the head displacement and subjective visual vertical, suggesting shared representation of frame of reference between perception and motor control as to the gravity information.

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Poster Session F > Perception and Action > Poster F63

Members of highly entitative groups are implicitly expected to behave consistently based on their deep-level goals instead of their shallow-level movements

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The current study investigated whether the deep properties or shallow features of behaviors are implicitly expected to be consistent across members of highly entitative groups by exploiting the notion that goals—as deep properties—and movements—as shallow features—can be dissociated in object-directed behaviors. Participants were asked to view group members' goal-directed behaviors toward an object. Whether perceivers implicitly expected that a new member would perform the same movement to the previously visited location (i.e., exhibit shallow feature-based behavior) or a new movement to the previously visited object (i.e., exhibit deep property-based behavior) was recorded. Study 1 revealed that perceivers implicitly expected members of a highly entitative group to approach the previously visited object with a new movement (i.e., to have a consistent goal) rather than perform the same movement to the previously visited location (i.e., to express a consistent movement). Study 2 confirmed that the responses in Study 1 were explained by group members conforming to, rather than violating, internal expectations (i.e., of consistent movement). Importantly, the implicit expectation of shared behaviors across group members relies on the goal interpretation of actions instead of the associations between actions and outcomes (Study 3). Study 4 replicated the facilitation effect of Study 1 and revealed that the goal-based expectation of common behaviors among group members is based on the majority behavior instead of a single demonstration. Hence, individuals in highly entitative groups are implicitly expected to behave consistently based on the deep properties of behaviors instead of their shallow features.

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Using model comparisons to reveal the mechanisms of confidence generation

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Humans have the metacognitive ability to estimate the accuracy of their decisions using confidence estimates. Several theories have attempted to describe the computational mechanisms of confidence generation by instantiating process models. Yet, there has been little work on comparing these models using the same data. In this study, we aim to uncover the computational mechanisms of confidence generation by extensively comparing models on their ability to fit confidence data and predict behavior, while simultaneously establishing a multi-dimensional framework for robust model comparisons. We fit twelve popular process models to a large dataset (20 subjects, 2,800 trials/subject) in which participants completed a perceptual task with confidence ratings. Our quantitative comparisons show that the best fitting model postulates a single system for generating both choice and confidence judgments where confidence is additionally corrupted by signal-dependent noise (Shekhar & Rahnev, 2020; Psych Review). These results suggest that dual processing assumptions – according to which confidence and choice arise from coupled or independent systems – is unnecessary. Model evidence also contradicted popular notions that confidence is derived from post-decisional evidence or posterior probability computations. Further, qualitative analyses revealed that the best fitting models were those that could closely predict individual variations in metacognitive ability and zROC functions. On the other hand, the worst performing models were characterized by a failure to predict the folded X-pattern, which is considered a basic feature of confidence. Finally, through model recovery analyses, we also establish practical guidelines for designing experiments that allow us to maximally discriminate between models. Together, these analyses establish a general framework for model evaluation that also provides qualitative insights into their successes and failures. Most importantly, these results, by confirming and falsifying theories about confidence, begin to reveal the nature of metacognitive computations.

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Eye–hand coordination reveals the role of body awareness in motor control

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Awareness of the body includes awareness of visible body parts as one’s own (sense of body ownership) and awareness of voluntary actions over those visible body parts (sense of agency). How these senses affect motor control remains unclear. To address this issue, the present study combined the moving rubber hand illusion, which allows experimental manipulation of agency and body ownership over an artificial hand, with the finger-tracking paradigm, which allows behavioral quantification of motor control by the ability of eye–hand coordination. Eye–hand coordination requires awareness of the hand to track the hand with the eyes. In this study, participants tracked a finger of a moving artificial hand with their eyes while the artificial hand moved together with the participant’s hidden hand. The present results show that eye–hand coordination is improved when participants experience a sense of agency over the tracked artificial hand, regardless of their sense of body ownership. Moreover, the eye latency (defined by eye onset time relative to hand onset time) significantly correlated with the strength of sense of agency, but the pursuit gain and number of saccades did not. Eye latency is an indicator of how fast the onset of hand movements evokes pursuit eye movements in the initiation of eye–hand coordination. Pursuit gain and number of saccades are indicators of how precisely pursuit eye movements track hand movements during the maintenance of eye–hand coordination. Thus, the present findings indicate that the improvement by sense of agency is selective for the initiation, but not maintenance, of eye–hand coordination. This suggests that the experience of explicit sense of agency over one's body parts improves the initiation of voluntary motor actions, implying that artificial manipulation of agency may be beneficial to rehabilitation and sports training techniques.

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Working memory load affects both motor replanning and execution

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Extensive evidence has shown that movement sequences of motor planning are temporarily stored in working memory (WM) and thus interfere with the storage of other information. However, it remains controversial whether holding information in WM would reversely influence motor planning/replanning. The current study addressed this issue by adapting an anti-pointing task that would force motor-replanning. During the experiment, there were two squares constantly on the left and right sides of the screen, respectively. On each trial, a set of letters (set size: 2-6) were first presented, evenly distributed on the two sides of the screen. After the offset of the letters, one of the letters was presented on the center of the screen again and the participant was asked to indicate which side the letter was once on by pointing. There were two blocks, a “pro-pointing only” block and a “pro-pointing + anti-pointing” block for each participant. In the “pro-pointing only” block and half trials of the “pro-pointing + anti-pointing” block, the target letter was light-grey and the participant should move the index finger to touch the square that was on the same side of the target letter. In the other half of trials of the “pro-pointing + anti-pointing” block, the target was red and the movement should be toward the square on the opposite side. The initiation time of hand movement increased when set size increased and one key finding here was that this set size effect was larger for the anti-pointing trials, compared to pro-pointing trials in the “pro-pointing only” block. This finding, with the result that the trajectory of movement became more center-biased with the increase of set size, indicates that holding information in WM slow down motor replanning and affected the execution, suggesting a source competition between movement planning/replanning and cognitive processes.

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Confidence computation incorporates both task-relevant and task-irrelevant noises unlike decision making

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The current study investigated how task-relevant and task-irrelevant noises are incorporated into decision making and confidence computation. To answer this question, we manipulated the levels of white noises embedded in oriented Gabor patches while maintaining their RMS contrast equal. We presented eight Gabor patches with different orientations and asked participants to report the orientation of a target and their confidence simultaneously. The target was designated by a retro-cue. Our variables of interest were the level of noise added to a target (local noise) and the average level of noises added to all items including distractors (global noise). As participants were asked to judge a single target orientation, the local noise was task-relevant and the global noise was task-irrelevant. Overall, we found that confidence computation was more sensitive to noises than decisions at both local and global levels. First, when the level of global noise was low, decision accuracy did not vary depending on the level of local noise. However, the degree of confidence decreased when the target had a higher local noise level regardless of the actual correctness of the decision. Second, when the level of local noise was constant and only global noise increased, decision accuracy remained the same. Interestingly, the degree of confidence increased following the increased global noise regardless of the actual correctness of the decision, suggesting that confidence can become higher when distractors were noisier than the target. Finally, when both the level of local and global noises was high, both decision accuracy and confidence decreased. In sum, our results show that confidence incorporates both task-relevant and task-irrelevant noises whereas decision only partially incorporates task-relevant noise.

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Poster Session F > Perception and Action > Poster F68

The Occipital Place Area Encodes the Existence of an Obstacle

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The ability to navigate through various environments is crucial for all mobile organisms. Recent body of work has suggested that the occipital place area (OPA) encodes information crucial for spatial navigation, especially by utilizing boundaries (i.e. walls) which define the spatial structure of a scene. However, little is known about the role of objects, which might change the navigability by obstructing the possible path. Here, we tested whether the OPA and other scene-selective regions (PPA, RSC) encode the presence of an obstacle. During fMRI scan, participants performed one-back repetition detection task while being presented with outdoor/open space images with an object (e.g. a rock) and a visible path shown on the ground. Four different conditions were created as a combination of path direction (to the Left vs. Right), and object location (on the Left vs. Right). The object served as an obstacle blocking the navigable path only when path direction and object location matched. By analyzing multi-voxel patterns in scene-selective regions using SVM classifiers (preliminary data, N=7), we found significant above-chance classification in the OPA for path direction, object location, and importantly, for obstacle presence. The current study is the first to demonstrate that the OPA encodes the existence of an object hindering the passage, namely obstacle . This result is striking in a sense that it signifies similar coding in OPA for the two exact opposite conditions (i.e. treating left-left and right-right path direction-object location pairs alike as “obstacle present”). Furthermore, the coding of non-surface navigational barrier in the outdoor/open space signifies that the OPA supports navigation even when no wall-like boundaries are present. Together, these results serve as an evidence that the OPA encodes the existence of obstacle through merged representation of path direction and object location, indicating its role beyond boundary-based navigation.

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Poster Session F > Perception and Action > Poster F69

Shape congruence modulates visuo-haptic interactions during binocular rivalry

View Poster | Visit me in Gather.Town Manatee Room on Monday 8:00 pm - 10:00 pm EDT

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When two dissimilar images are presented to the corresponding retinal positions of the two eyes, perception alternates between the two images (Blake & Logothetis, 2002). Dubbed binocular rivalry (BR), this paradigm provides a window into inferential visual processing. Recent experiments using multisensory stimuli found that tactile information boosts the dominance of the congruent visual stimulus (Lunghi et al., 2010; Suzuki et al., 2019). The present study examines whether dynamic haptic exploration of 3D shape objects boosts the perception of congruent visual shape stimuli during BR. 3D spiky and round shapes were created with a parametric shape model (Gielis, 2003). The coordinates for the neutral shape were acquired through linear interpolation of round and spiky shape coordinates (Kwak et al., VSS 2018). Visual and haptic stimuli were each created by 3D rendering and 3D printing the shape models. Participants viewed a pair of rotating round and spiky shapes as rival targets while exploring haptic objects with their left hand. They used their right hand to track perceptual dominance via computer key press. There were four haptic conditions - three exploring round, spiky, and neutral shape objects and one with no haptic stimulation (visual-only). Visual dominance durations for each condition were normalized with the mean duration of visual-only trials to account for individual differences. Analyses showed significant differences in the normalized dominance durations of both round and spiky visual targets when exploring haptic stimuli of different shapes. Specifically, haptic exploration of an object was associated with increased dominance of the corresponding visual target for both round and spiky shape during BR. With these results based on stimuli parametrically modulated in a single shape dimension of curvature, we suggest that shape congruence between visual and haptic modalities boosts the dominance of the corresponding visual target.

Acknowledgements: Supported by NRF-2020R1F1A1076336

Object Recognition

Poster Session F > Object Recognition > Poster F81

Towards acquisition of shape bias: Training convolutional neural networks with blurred images

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ImageNet-trained Convolutional Neural Networks (CNNs) classify objects relying more on texture features than on shape features (texture bias), while humans show the opposite shape bias (Geirhos et al., 2019). We suspect that humans' shape bias may be acquired by experiencing both sharp and blurred images during early visual development (starting from a blurred visual world), and/or in daily life (where optical blurs are often produced by ocular defocus, and atmospheric light scattering). To test this idea, we trained AlexNet with original sharp images (S-Net), with Gaussian-blurred images (B-Net), and with a mixture of blurred and sharp images (B+S-Net). In comparison with S-Net, B-Net showed a higher shape bias, but a lower classification accuracy with sharp images. B+S-Net, on the other hand, showed a higher shape bias, with keeping high classification accuracies with both sharp and blurred images (blur robustness). The degree of shape bias shown by B+S net was not as high as those of humans and AlexNet trained with unnatural Stylized ImageNet (Geirhos et al., 2019), but comparable to that of VOneNet (Dapello et al, 2020). Another training condition simulating the time course of infant development (trained initially with blur images and later with sharp images, B2S-Net) showed intermediate characteristics between S-Net and B+S-Net. B2S-Net might behave more like B+S-Net with additional mechanism to avoid forgetting of early experiences, such as critical periods. To understand how our trainings led to enhanced shape bias and blur robustness, we visualized the receptive fields of the first convolutional layers, and found that spatial frequency tuning was shifted to the lower range for B+S-Net in comparison with S-Net. Furthermore, the representational dissimilarity matrices (RDM) indicated that sharp images and blurred images are represented similarly in higher convolutional layers of B+S-net, suggesting development of frequency-invariant representations by blur mixed training.

Acknowledgements: This work was supported by JSPS KAKENHI Grant Number JP20H00603.

Poster Session F > Object Recognition > Poster F82

Microgenesis of orientation appearance during common-onset masking

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A target is rendered less visible by a sparse mask with common onset and delayed offset relative to the target. Studies of this common-onset masking (COM) usually measure visibility by determining target discriminability. However, our conscious experience contains suprathreshold appearance as well as visibility. In VSS 2020, we reported that COM alters appearance by reducing orientation repulsion that normally occurs when a vertical target is surrounded by tilted inducers. Here, we examined the time course of this reduction by limiting the temporal position of inducers. Observers were asked to indicate whether a vertical target, a Gabor patch, presented for 33 ms appeared tilted clockwise or counter-clockwise. The inducer was composed of eight equally-spaced Gabor patches along a virtual circle concentrically surrounding the target. The inducer duration was fixed at 67 ms, and the target-inducer SOA was varied. As a mask, we presented five dots placed at each vertex of a virtual inverted pentagon (having no vertical orientations) concentrically surrounding the target. In the simultaneous-offset condition, the mask appeared and disappeared together with the target. In the delayed-offset condition, the target and mask appeared together but the mask remained 300 ms after the target disappeared. In the no-mask condition, the mask was not presented at all. The repulsion occurred not only when the inducer was simultaneous with the target but also for earlier and later inducers. Nevertheless, the mitigation of repulsion caused by COM occurred only for later inducers. In addition, orientation discriminability was not deteriorated regardless of the mask offset conditions. It is suggested that COM broadly terminates temporal evolution of internal representations, influencing diverse phenomena beyond the well-known visibility reduction, such as the contextual modulation of the suprathreshold appearance of orientation. Some updating process to alter object representations from the target to the mask might trigger this termination.

Acknowledgements: Supported by KAKENHI 18H05523

Poster Session F > Object Recognition > Poster F83

Absence of object substitution masking in early infancy

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In object substitute masking (OSM), target perception is impaired when a target is briefly presented with a surrounding mask that remains on-screen after the target disappears. Several studies suggest that this phenomenon arises from a disruption of recurrent processing. Here, we investigated OSM in 3–8-month-old infants using a preferential looking paradigm with face stimuli. A face and three distracters were presented for 250 ms, where the face was surrounded by four dots (mask). In the delayed-mask offset condition (masked condition), the mask remained on the screen for 250 ms after the target disappeared. In the simultaneous-offset condition (unmasked condition), the target and mask disappeared simultaneously. The stimulus sequence was repeated for 11 s on each trial. The two conditions were presented alternately and were repeated five times. If OSM occurs, faces cannot be perceived in the masked condition, and looking times for the stimulus array would be longer in the unmasked condition. The results showed that 7–8-month-old infants looked longer in the unmasked condition, while 3–6-month-old infants did not, suggesting that OSM only occurs in older infants. To further test the absence of OSM in younger infants, we conducted an additional experiment to compare the masked condition with a no-face condition. The no-face condition was same as the unmasked condition, except that the face was replaced by a blank. If OSM does not occur, looking time would be longer in the masked condition. Infants at 3–6 months showed longer looking time in the masked condition, while 7–8-month-old infants did not. These results indicate that infants under 7 months are immune to OSM, and they can perceive faces that older infants cannot because of masking. Our findings suggest that recurrent processing is immature in early infancy, and they can perceive objects even without mature recurrent processing.

Acknowledgements: Supported by Grant-in-Aid for Young Scientists (19K14479)

Poster Session F > Object Recognition > Poster F84

Simultaneous and sequential subitizing share a common object individuation-based mechanism: Evidence based on resource competition

View Poster | Visit me in Gather.Town Dolphin Room on Monday 8:00 pm - 10:00 pm EDT

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Human observers adopt two types of strategies for rapid enumeration -- subitizing and estimation for small and large sets, respectively. According to spatial and temporal presentations of numerical stimuli, subitizing can be divided into simultaneous subitizing and sequential subitizing. Previous studies had shown that simultaneous subitizing is related to object individuation (a process of separating each item in a set from other items, based on its temporal or/and spatial characteristics). However, there is so far little research to tackle the underlying mechanism of sequential subitizing and no study to explore directly whether these two types of subitizing share a common object individuation-based mechanism. The present study pits the two subitizing types against each other in a dual-task paradigm. Participants were required to complete a sequential enumeration task overlapped temporally with a simultaneous enumeration task. Our results demonstrated that the sequential enumeration significantly influenced the simultaneous subitizing, even after the effects of mere physical exposure were partialled out. Comparing to a dual-task composed of sequential counting and simultaneous subitizing, a significant "resource competition" was revealed for a dual-task composed of sequential subitizing and simultaneous subitizing, manifested by increased error rates and decreased accuracy and precision. In contrast, the sequential enumeration had no such a carry-over effect on the simultaneous estimation when object individuation is not involved. Taken together, our study demonstrated that simultaneous and sequential subitizing share a common object individuation-based mechanism. When these two types of subitizing were temporally close to each other, a "resource competition" can occur, likely due to the limited capacity of object individuation processing.

Which comes first? Examining breaking continuous suppression time of high-calorie and low-calorie foods

View Poster | Visit me in Gather.Town Dolphin Room on Monday 8:00 pm - 10:00 pm EDT

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Food is indispensable in our daily life, as food provides us with energy and consequently is highly correlated with our metabolic and visual systems. Previous studies showed that people unknowingly complete tasks related to calorie evaluation and prefer high-calorie foods to low-calorie foods, suggesting that caloric information can be processed automatically. However, there is still a gap between automatic processes and unconscious processes. The present study aimed to investigate whether food information can be processed without visual awareness. In the series of experiments, we adopted the breaking continuous flash suppression (b-CFS) paradigm to investigate if the time for high-calorie and low-calorie food to access awareness differ. By adopting both food pictures and their corresponding two-character Chinese words as targets, Experiment 1 showed that high-calorie food pictures broke CFS faster than low-calorie food pictures, whereas the opposite pattern was found for high-calorie and low-calorie words, suggesting that the mechanisms of unconscious processing in pictures and words are different. Experiment 2 used diffeomorphic transformed pictures, where pictures are distorted but preserves all visual features, from Experiment 1 as targets. The results showed that the b-CFS times did not differ between high-calorie and low-calorie transformed pictures, suggesting that low-level features in the pictures did not contribute to the difference of b-CFS times across calories in Experiment 1. Furthermore, we also showed that the results in Experiment 1 were free from response bias, as detection times for high-calorie food and low-calorie food were similar in the binocular viewing condition. Together, our results showed that meanings of pictures and words can both be processed unconsciously, suggesting high-level information can survive under CFS.

Acknowledgements: This research was supported by Grants from Taiwan's Ministry of Science and Technology (MOST 107-2410-H-002-129-MY3).

Tell the difference between pictures made by artists and computers: Categorization and evaluation

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Aesthetic perception has long been an interest of many researchers. Examining what kinds of pictures are perceived to be beautiful, people can judge abstract paintings drawn by professional artists to be more valuable than those drawn by children or animals (Hawley-Dolan & Winner, 2011). In addition, people can distinguish between abstract paintings drawn by professional artists and those drawn by children or animals (Snapper et al., 2015). On the other hand, computers have recently become capable of drawing pictures similar to those of people. Studies that have attempted to distinguish between computer-generated abstract paintings and human-generated ones have shown that it is difficult to detect the creator (Chamberlain et al., 2018). The question is, then, whether we perceive computer-generated paintings to be as beautiful as human-generated paintings. In other words, can computer-generated paintings include visually aesthetic features? Following psychological aspects of beauty (e.g., empathy, nostalgia; Batcho et al., 2008, Gerger et al., 2018) and philosophical aspects of beauty (e.g., Universality, wish to continue; Brielmann et al., 2020), we asked participants to rate the beauty of computer-generated paintings made by Art42 (https://art42.net/) based on StyleGAN2 (Karras et al., 2019) and human-generated paintings (from WikiArt). Two hundred and sixty participants participated via crowdsourcing and evaluated 80 paintings, and the results showed that they rated the human-made paintings as more beautiful than the computer-generated paintings in various aesthetic aspects including both psychological and philosophical perspectives. However, when they were asked to identify whether the painting was created by a human or

a computer, the correct answer rate was just 49.7%, indicating that they could not distinguish the creator. These results suggest that aesthetic perception of art is judged from a place other than the surface elements of the painting (e.g., straightness of lines or lightness of colors), which is elaborated by machine learning.

Acknowledgements: JSPS KAKENHI #19K14472

Poster Session F > Object Recognition > Poster F87

Toward a general model of visual art perception - the role of expertise and culture.

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If all humans share a common capacity for experiencing and appreciating artworks, it is plausible that the underlying neural/cognitive mechanisms are also common across cultures. Arts exist in many forms (e.g. paintings, music, dance), have major distinctions (e.g. abstract or representational art), and are enjoyed by art experts and non-experts alike. Extant literature provides little evidence for constructing a general model of the perception of visual art. In the current study, across different art forms (paintings, dance), we investigate whether mechanisms underlying aesthetic appreciation of abstract and representational art are similar/different, are modulated by expertise, and are universal i.e. similar across cultures. In Experiment 1, participants (N=100) from India and Europe (50 experts, 50 non-experts) rated Indian and Western abstract and representational paintings on beauty and liking (and familiarity, evocativeness, complexity). Preliminary results suggest that representational paintings were liked more and found to be more beautiful compared to abstract paintings, but only for non-experts. This interaction was consistent across both cultures of participants and paintings (Indian/Western) and there was no evidence of an ingroup bias – Indian participants did not prefer Indian paintings more than western paintings. In Experiment 2, instead of paintings, dance experts and non-experts rated abstract and representational ballet (western classical) and Bharatanatyam (Indian classical) dance videos. Experiments 3 and 4 are ongoing and investigate the neural mechanisms of visual art appreciation across cultures and expertise. Almost all cultures around the world produce or perform artworks that are appreciated for their aesthetic or artistic qualities. The current findings have implications for building a generalizable model of the perception of visual art that is inclusive of different art forms as well as cultures.

Binocular Vision

Poster Session F > Binocular Vision > Poster F88

The Relationship Between Daytime and Nighttime Stereoacuity

View Poster | Visit me in Gather.Town Dolphin Room on Monday 8:00 pm - 10:00 pm EDT

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Good stereoacuity in a wide range of illumination conditions is important for professionals such as surgeons and pilots. Most stereoacuity measures are conducted in daylight viewing conditions, providing information about daytime stereoacuity, whereas less is known about nighttime stereoacuity and the relationship between them. In the current study, we designed two computerized stereopsis tasks to be conducted in low-illuminance conditions. We compared daytime and nighttime stereoacuity, as measured using a Functional Visual Analyzer (FVA), a clinical screening tool. The first task, which was modified from the FVA's setting, required participants to detect which one of four circles was on a different depth plane. The second task required participants to determine whether a target line presented at varying depths was in front of or behind a comparison line on a fixed plane. For both tasks, stereoacuity was defined as the minimum binocular disparity at which a participant could perform the tasks. We recruited 53 participants aged 22–40 ($M = 26.06 \pm 4.28$) with no ocular diseases and visual acuity better than 20/25. The FVA measures showed no significant difference between daytime and nighttime stereoacuity ($M \pm SD = 31.70 \pm 16.73$, 33.58 ± 27.86; $t = -.538$, $p = .593$), but

they were positively correlated with each other (r = .433, p = .001). The thresholds measured in both tasks correlated significantly with nighttime stereoacuity (r = .323, p = .018; r = .300, p = .029), but only the first task correlated with daytime stereoacuity (r = .275, p = .046; r = .101, p = .470), indicating that the tasks conducted in the current setting were suitable for measuring nighttime stereoacuity. The results further indicate that the underlying mechanism for nighttime stereoacuity might differ from that of daytime stereoacuity and cannot be assessed using existing clinical screening tools.

Poster Session F > Binocular Vision > Poster F89

Three-dimensional depth estimation of virtual objects in augmented reality

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Accurate three-dimensional (3D) depth perception of virtual objects is important for immersive augmented reality (AR). However, it is unclear whether/how 3D depth perception of virtual objects in AR differ from real objects as previous studies have reported mixed results showing both the underestimation and overestimation of an virtual object's 3D depth. These discrepant results might be due to individual differences in inter-pupillary distances (IPDs), different devices used for research, and the interaction between those two factors. Here, we used a commercial AR device (Epson Moverio BT-35E) and measured 3D depth estimation of virtual objects rendered at reaching (34-50 cm) and room-scale (100-300 cm) distances in a perceptual depth matching task. Specifically, we compared the pixel disparity between the left and the right display calculated from the stereo camera model with the reported pixel disparity during the depth matching task at each distance. Next, we measured pixel offsets due to the mismatch between the inter-display distance (IDD; distance between each display on the device, 6.5 cm) and the individual IPD, and tested whether the calibration based on the individual IPD improve 3D depth estimation. Our results show that our observers (n= 11) overestimated the 3D depth of virtual objects at 34-50 cm and underestimated at 150-300 cm with near-perfect estimation at ~100 cm. Furthermore, our calibration method improved 3D depth estimation at 150-300 cm, progressively reducing underestimation as distance increases (by an average of 45%). Our findings suggest that the 3D depth estimation of virtual objects in AR changes from overestimation to underestimation as the rendered distance increases from reaching to room-scale distances, and that a simple calibration by compensating the mismatch between IDD and the individual IPD may help each individual's immersive AR experience especially for commercial AR devices without IPD adjustment functionality.

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Poster Session F > Binocular Vision > Poster F90

The effect of binocular disparities on the Mona Lisa effect: Examination of the effect of disparities given to different components of a portrait

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The gaze and face orientation of a person depicted in a portrait painting appears to follow observers when they move around. This is called the Mona Lisa effect (MLE). The binocular gradient of disparity on the picture surface indicates the slant of picture surface, but pictorial cues from the facial parts (relative positions and occlusions between them) indicate the face is facing straight to the observer. Morita et al. (2020) showed that the existence of pictorial cues suppresses the functioning of binocular disparities when the MLE occurs. In this study, we examined the effect of disparities given to the background, the external frame, and the face on the occurrence of MLE by using the perceived facial width of slanted portrait as an index as for our previous study. In Experiment 1, we presented 2D portraits rotated ±30 degrees around z-axis as test stimuli and a line-drawing oval as the reference. We used lowpass-filtered random-dot texture as the background to enhance the disparity cues. Observers judged which, the face or the reference, appears wider. The results showed that the MLE intensity was almost equal regardless of the existence of background. In Experiment 2, we measured the MLE intensity for portraits containing disparity only in the external frame or only in the facial part, and

compare the results with those obtained from portraits containing disparities in both components. It was found that the intensity was almost equal between the three conditions. In sum, the present results demonstrated two intriguing aspects of the MLE; (1) the disparity gradient given to the picture background does not affect the intensity of MLE, and (2) the disparity given to either the picture frame or the facial part, or both generate the MLE of about the same intensity.

Poster Session F > Binocular Vision > Poster F91

Relationship between the disparity tuning symmetry and responses to anti-correlated random dot stereograms in macaque areas V2, V3 and V3A

View Poster | Visit me in Gather.Town Dolphin Room on Monday 8:00 pm - 10:00 pm EDT

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Binocular disparity, an important depth cue, is initially represented by computing the cross-correlation between the left-eye and right-eye images (correlation-based representation). This process takes place in the primary visual cortex (V1). In later processing stages within and beyond V1, this primitive representation is refined into a match-based representation, which reflects the strength of feature matching between the left-eye and right-eye images and discards responses to falsely matched features. Although other mechanisms must also be involved, a nonlinearity is a well-supported mechanism to transform the correlation-based representation into the match-based representation. Some physiological studies find that V1 responses have this nonlinearity. Also, simulations with the nonlinearity suggest that neurons with odd-symmetric tuning have more correlation-based response properties than those with even-symmetric tuning. To examine whether later processing stages beyond V1 have this nonlinear property, we analyzed neural responses to correlated and anti-correlated random dot stereograms (cRDSs and aRDSs) in macaque areas V2, V3 and V3A, which receive disparity signals from V1. The correlation-based representation should have inverted tuning functions for aRDSs relative to those for cRDSs; the match-based representation should lose disparity selectivity for aRDSs. We recorded neural responses from 54, 63 and 59 disparity selective neurons in V2, V3 and V3A while two monkeys performed a fixation task. Proportions of V2, V3 and V3A neurons with inverted tunings for aRDSs were close to 50%. In V2 and V3A, but not V3, neurons with odd-symmetric tuning tended to show inverted tuning curves for aRDSs more often than neurons with even-symmetric tuning. Thus, V2 and V3A were consistent with the simulation of binocular disparity computation with the nonlinearity. These findings suggest that responses in V2 and V3A, but not in V3, have the nonlinearity for transforming the correlation-based representation into the match-based representation.

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Poster Session F > Binocular Vision > Poster F92

Greebles in 3D: Depth sensitivity is altered by classification training involving novel objects

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Previous work has indicated that depth-position judgment can be influenced by the object's identity, raising an intriguing question as the role of object expertise in defining stereoscopic depth retrieval. In this study, we investigated whether training that attaches meaning (i.e., classification labels) to otherwise novel objects (i.e., Greebles), changes observers' sensitivity for judging their depth position. Observers (N = 20) completed an experiment comprising a pre-test session, 3-5 training sessions (depending on performance attainment), and a post-test session. In the pre-test and post-test stages, participants were presented with disparity-defined Greebles and asked to complete a noise-based depth position (near versus far) judgment task. In the training stage, participants were trained to associate disparity-defined Greebles with given names and gender. Results showed that depth discrimination thresholds were significantly lower (i.e., better) following Greeble-classification training, than before training, despite the fact that object identity is irrelevant to judging depth-position. Performance did not change between "pre" and "post" tests for two additional groups: (1) a group (N =

13) who completed tests and re-tests without classification-training; and (2) another group (N = 13) who completed tests and re-tests, but trained on an orientation task (using identical stimuli), rather than on the Greeble-classification task. Our data suggest that depth sensitivity can be actively altered through acquiring object meaning for otherwise nonsensical objects, highlighting a robust interplay between object recognition mechanisms and stereoscopic outcomes.

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Poster Session F > Binocular Vision > Poster F93

Content-Based Interaction Between Mask and Target in Continuous Flash Suppression

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In recent years the results from studies employing Continuous Flash Suppression (CFS) have been used as evidence that stimuli that do not reach consciousness are still processed to some degree by the visual system. However, little is known about whether a given type of CFS mask works equally well for all kinds of targets, or if different targets may be suppressed to different degrees. To investigate this, we employed a b-CFS paradigm with photographic face/house stimuli as targets. Faces are well known to break CFS faster than houses, in particular when using traditional Mondrian masks. These are very rectangular in their content, emphasizing cardinal orientations, and are thus hypothesized to match houses better than faces, possibly giving an “unfair” advantage to the face stimuli. To counter this, we designed random noise masks to match the spatial frequency and orientation contents of each individual target image (target-matched), thus ensuring fairness across target categories. As a more general alternative, we also generated masks from the average spatial frequency and orientation contents across both target categories. Data from 24 participants replicated the face advantage with Mondrian masks (13.5% faster, $t(23)=3.60$, $p=0.002$). Even with the target-matched masks, faces still broke suppression faster than houses (4.3% faster, $t(23)=3.07$, $p=0.005$); however the difference was significantly smaller ($t(23)=2.45$, $p=0.022$). Using the average masks, the face advantage remained as well (11.1% faster $t(23)=5.47$, $p<0.001$), however the difference was larger than with the target-matched masks ($t(23)=2.83$, $p=0.009$). We conclude that, while faces are privileged in the visual system even before reaching awareness, a portion of that advantage (here more than 60%) may actually come from unbalanced masking or unintentional mask-target interaction rather than the target stimuli alone. CFS masks should be carefully designed to optimally match the desired target material, otherwise results may suffer from potentially fatal bias.

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Feature-CoAlignment Between Mask and Stimulus Affects Suppression Depth in Continuous Flash Suppression

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Continuous Flash Suppression (CFS) has become a popular tool in the study of visual processing in the absence of conscious awareness. A variety of masks have been used in CFS studies; however it remains unclear wether CFS works globally (suppressing everything equally) or feature based, possibly allowing for effects of mask-stimulus interactions. Such interactions might then severely bias the results of CFS experiments by affecting different target categories unequally. We designed a b-CFS experiment with feature-specific targets and masks in order to investigate possible effects of feature-coalignment or -orthogonality to identify mask-target interactions. Masks were pink noise patterns filtered with a narrow-orientation band pass to generate a strong directionality in the visual appearance. Target stimuli were Gabors (sinusoidal patterns in a Gaussian envelope) varying systematically in their orientational alignment

with the masks. Implementing both masks and targets grayscale (luminance) patterns, the alignment between targets and masks significantly affected suppression duration (~80% longer for perfectly aligned pairs compared to orthogonal). This effect was stronger for cardinal orientations than for oblique orientations. When implementing both targets and masks as either primary RGB patterns or isoluminant color patterns, generally there was significant suppression between mask-target pairings of both identical and different color (or color axis). The alignment effect however prevailed mostly for mask-target pairings of the same color (respectively the same color axis), but was diminished for mask-target pairings of different color. We conclude that mask-target interactions exist in Continuous Flash Suppression and appear to be feature-based. The human visual system can use orthogonality within a feature dimension or across feature dimensions to facilitate the breaking of the CFS. Further, luminance differences between masking stimuli are not required to achieve suppression, CFS therefore functions under isoluminant conditions.

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Poster Session G

Attention: Individual differences, spatiotemporal, reward, social

Poster Session G > Attention: Individual differences, spatiotemporal, reward, social > Poster G1

Human talent and career development: Distinct cognitive profiles of STEM versus non-STEM professionals and college majors

View Poster | Visit me in Gather.Town Osprey Room on Tuesday 8:00 am - 10:00 am EDT

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STEM (science, technology, engineering, and mathematics) careers are considered essential for economic development and, on average, are better paying and more prestigious than non-STEM careers. Because more prestigious careers tend to be held by individuals with high scores on measures of general intelligence, general intelligence alone could be sufficient for predicting whether individuals pursue STEM or non-STEM careers. However, prior research has demonstrated that specific cognitive aptitudes sometimes better predict STEM pursuits, raising the possibility that STEM and non-STEM groups possess distinct cognitive strengths. To characterize the cognitive profiles of STEM versus non-STEM professionals and college majors, the present study recruited a large (N = 32,721), demographically diverse international sample to complete cognitive tasks requiring fluid cognition (matrix reasoning), crystallized cognition (vocabulary), spatial attention (multiple object tracking), and memory for faces (Cambridge Face Memory Test). STEM individuals performed better on the fluid cognition and spatial attention tests, whereas non-STEM individuals performed better on the crystallized cognition and face memory tests. These results, which were consistent across age and gender, demonstrate that STEM and non-STEM groups are characterized by distinct cognitive strengths, rather than simply differing in general intellectual ability.

Poster Session G > Attention: Individual differences, spatiotemporal, reward, social > Poster G2

Fluctuations of Visuospatial Attention are Predicted by Behavioral and Neuropsychological Measures

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The ability to successfully allocate attention and filter distractors is crucial for performing most daily tasks. Attentional performance varies both between as well as within individuals across different time spans. However, questions remain regarding the relationship between these fluctuations, lifestyle patterns, and physical/mental health characteristics. The aim of the current study was to identify state and trait factors which modulate fluctuations of visual attention across time. We loaned an iPad to 39 clinically healthy participants who performed the Attention Network Test (ANT; Fan et al., 2002) four times per day (morning, afternoon, evening and night) over a 12-day period. The ANT measures three subprocesses of attention: alerting, orienting, and distractor filtering. Additionally, subjects logged numerous variables relating to lifestyle choices such as diet, exercise, and sleep patterns. On the first and last day of the study, participants completed a battery of neuropsychological questionnaires that measured multiple dimensions of physical and mental health. Our results show group level improvements in distractor filtering performance over time with the greatest changes occurring within the first four days of the study. In order to examine individual variability in attentional fluctuations, a Principal Component Analysis was performed on the longitudinal ANT data and K-means clustering revealed 4 groups of individuals. One of these clusters was uniquely characterized by markedly diminished improvements in distractor filtering (i.e., shallow slope over time) relative to the group average. Furthermore, individuals within this cluster differed along several other characteristics including greater lack of emotional awareness (as measured by the Difficulties in Emotional Regulation Scale), less variability in sleep, and less social media usage. The links between health-related factors and attentional fluctuations suggests significant predictive value of behavioral and

clinical measures within a sub-clinical population on distractor filtering improvement over two weeks of behavioral training.

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Poster Session G > Attention: Individual differences, spatiotemporal, reward, social > Poster G3

Expectation Modulates Performance Above the Effect of Attention in Two Dynamic Online Experiments

View Poster | Visit me in Gather.Town Osprey Room on Tuesday 8:00 am - 10:00 am EDT

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Several predictive coding theories of autism suggest that the difficulties observed in the autistic phenotype are a product of an imbalance of precision allocation between bottom-up and top-down signals. One proposed mechanism for precision allocation is attention. In two online experiments, we assessed the effects of independently modulating attention and expectation in a modified Posner paradigm using biological (BM) or coherent motion (CM) as the attentional cues. The expectation was modulated block-wise by explicitly instructing participants that 75% of targets would appear on one side of the screen, or that there was no prediction of target location. Thus, expected targets appeared on the side congruent with the block-wise cue, and unexpected targets on the opposite. Performance on the task was correlated with scores on the short Autism Quotient (AQ) questionnaire to investigate how participants' autistic traits affect their performance. Preliminary results show that in the BM task (N=40), attended and expected targets were detected faster compared to attended but unexpected targets or when no expectation was set. The difference between attended and unattended targets was larger in both the expected and unexpected conditions in comparison to when no expectation was set. In the CM experiment (N=37), we observed inhibition of return where participants were slower at detecting attended targets as opposed to unattended. This was true for all expectation conditions. Expectation still showed a main effect, leading to faster detection of expected compared to unexpected targets. At this point, the effects of AQ were only observed in the BM experiment, where higher AQ scores led to slower reaction times. Although we cannot draw a conclusion about the effect of AQ on performance at this stage, these preliminary results suggest that expectation primes responses, above the effect of attention, and hinders performance if information is not expected despite being attended.

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Poster Session G > Attention: Individual differences, spatiotemporal, reward, social > Poster G4

The Influence of Reward History on Goal-Directed Visual Search

View Poster | Visit me in Gather.Town Osprey Room on Tuesday 8:00 am - 10:00 am EDT

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The attentional priority of a stimulus is influenced by both its relationship to task goals and reward history. Although which stimuli receive goal-directed attentional priority may at times be dictated by task demands, as is the case in many paradigms used to study visual search, in many real-world situations individuals need to choose what to search for. In such situations, it is unclear how reward history might influence attentional control when previously reward-associated stimuli are potential targets. In the present study, participants (n=31) completed a modified version of the Adaptive Choice Visual Search (ACVS) task which requires participants to search for one of two color targets on each trial; the number of non-targets in each color varies trial-to-trial. Thus, to maximize performance, the optimal strategy would be to search through whichever color stimuli are less plentiful. In the present study, we introduced a training phase in which the only one of two color targets was present on each trial, one of which was associated with monetary reward when correctly reported. In the subsequent test phase, participants completed the ACVS task in which the previously reward-associated color could be the optimal (less plentiful) color, the non-optimal color, or neither color was optimal. Our findings reveal that, in the test phase, participants were biased to search through the previously reward-associated color

regardless of whether it was optimal to do so. Furthermore, participants were significantly slower on trials in which the previously reward-associated color was the non-optimal color compared to each of the other two trial conditions These results provide evidence that reward history biases goal-directed visual search even when searching for the previously reward-associated stimulus entails a performance cost.

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Sustained orienting of attention and microsaccades with dynamic social cues require the joint presence of heads and bodies

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Tuesday 8:00 am - 10:00 am EDT

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Introduction: Gaze, head, and body postures are socially important cues to indicate future actions and intentions (Emery, 2000) and orient attention reflexively (Driver et al., 1999; Friesen et al., 2004). Most previous studies used static drawings of heads/bodies and simple targets (Azarian et al., 2017; Bayliss et al., 2004). Here, we investigated how people's dynamic looking behaviors that include their head and body movements contribute to the orienting of attention in an ecologically relevant person search task. Method: Thirty subjects searched for a target person (yes/no task; present in 50 % of trials) in sixty videos of real-world scenes while maintaining central fixation. One through three individuals in the videos dynamically looked towards the same location. After a random onset (200ms or 500ms), additional individuals appeared in the video, including at the "looked at location". In half of the target-present trials, individuals in the videos oriented their gaze to the target's location (valid-look trials), while in the remaining 50 % they looked at a distractor person (invalid-look trials). Videos were manipulated so that looking individuals (but not targets and distractors) contained: entire silhouettes, floating heads, and headless bodies. Results: The cueing effect (d'valid – d'invalid) was strongest with the joint presence of heads and bodies and temporally sustained (Δd' 200ms: .34, $p<.05$; 500ms: .45, $p<.01$). The cueing effects for the floating heads and headless bodies were not significant for the 500ms delay (Δd'= .06, p =. 66; Δd' = .13, p = .62m, respectively). We also found a sustained bias in microsaccades direction toward the validly cued direction for the silhouettes (200ms :70.34%, 500ms: 64.46%, both $p<.05$) but not for the floating heads and headless bodies conditions. Conclusion: The joint presence of heads and bodies is critical for engaging sustained covert attention and microsaccades during search in dynamic scenes.

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Gaze following and mental state attribution: the agent's line of sight moderates the gaze cueing effect

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Tuesday 8:00 am - 10:00 am EDT

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Do humans follow gaze to locations that the gazer cannot see? Previous work using the gaze-cueing paradigm has found that obstacles blocking the gazer's line of sight did not decrease the gaze-cueing effect at 400ms SOA (Cole et al., 2015). This suggests that the early gaze-following responses are insensitive to context. Here we hypothesize however that a simple lack of salience in the crucial manipulation of line of sight may be responsible for the lack of an effect. Experiment 1 (N = 38) conceptually replicated the previous study by Cole and colleagues (ibid.). Here, barriers were positioned such that in each trial, the agent could see either both the possible target locations, or none. In line with previous findings, the cue validity * sightline interaction at 400ms SOA was not significant (F = .07, p = .79), and the difference in the gaze cueing effect was small: 60ms vs. 56ms in the seeing vs. non-seeing conditions. In Experiment 2 (N = 58) the barriers were positioned such that they blocked the view of either one target location or the other, thus making salient in each trial the difference between where the agent could see vs. not. In contrast to the first experiment, the size of the gaze cueing effect differed significantly at 400ms SOA depending on whether the agent could see the target (cue validity * sightline interaction, F = 6.42, p = .014). The seeing condition yielded a gaze cueing effect of 77ms [95% CI 57ms, 97ms], whereas the non-seeing condition yielded a much smaller gaze cueing effect of 46ms [95% CI 26ms, 65ms]. We conclude then that the agent's line of sight affects the magnitude of gaze cueing effects, but this only holds when the manipulation of this factor is made sufficiently salient within individual trials.

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Social settings and motivation affect attentional capture

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Tuesday 8:00 am - 10:00 am EDT

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The relationship between stimulus-driven and goal-directed control in attentional capture is still complicated. Research has primarily involved single participants in isolated settings. The aim of this work was to investigate the impact of social settings and social motivation on attentional capture. In Experiment 1 (n= 60), participants were paired up and conducted a typical attentional capture task together. One participant searched for a salient colour singleton and the other participant for a non-salient shape singleton, each responding to a line element in their targets. The defined target for one participant was the to-be-ignored distractor for the other participant. Participants sat next to one another and shared keyboard. In the ‘together’ condition, both players responded to their targets; in the ‘alone’ condition, the partner was observing only. Replicating previous research, attentional capture was found in the shape-singleton responders, but not in the colour-singleton responders. Critically, when the shape-singleton responders were doing the task together they responded reliably faster and the amount of capture was reduced, compared to when doing they were doing the same task alone. Together, people were less distracted. In Experiment 2 (n= 120), each individual in the pair responded to the shape singleton but either in a competitive (aiming to outperform the partner) or a collaborative setting (working together to outperform other pairs). The results showed that the competitive group responded reliably faster showing reduced capture compared to the collaborative group. Competition resulted in less distraction. In a third on-going experiment, social motivation is manipulated via an experimenter on Zoom to investigate whether similar social contingencies can exist in on-line settings. The present results suggest that attentional capture is very malleable and influenced by higher-level social settings. This work demonstrates that social motivation modulates the relationship between stimulus-driven and goal-directed control, further complicating the debate in attentional capture.

Poster Session G > Attention: Individual differences, spatiotemporal, reward, social > Poster G8

The Effect of Exogenous Temporal Attention on the Gradient of Spatial Attention

View Poster | Visit me in Gather.Town Osprey Room on Tuesday 8:00 am - 10:00 am EDT

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The gradient model of spatial attention states that resources of attention are concentrated in the center of focus and gradually decrease as we move our attention away from the center. Previous studies indicate that triggering temporal attention can significantly improve the subjects’ overall performance in attention tasks. In this study, we aim to investigate the effects of temporal attention on the distribution of spatial attention over increasing distance. In our task, two types of trials are presented to the subjects, Rhythmic and Arrhythmic. In rhythmic trials, temporal attention is evoked using an auditory rhythmic cue that indicates the onset of the targets' appearance. In all of the trials, spatial attention is engaged by a circular cue appearing at 7 degrees of visual angle from the fixation cross. Targets are presented at 9 degrees of visual angle in one of five possible distances from the cue. We compared the performance of our subjects in the rhythmic and arrhythmic trials over our various distances. We found that temporal attention significantly improves the reaction time of the correctly answered trials in all distances. Moreover, consistent with the gradient model, the performance gradually decreases as the target moves further from the cue in arrhythmic trials. More interestingly, in rhythmic trials, the participants show the best performance in the third (middle) distance from the cue, and it gradually worsens, as we move away from the middle distance. To be more specific, in rhythmic trials, the gradient model is still noticeable; However, the center of attention is dislocated from the closest position to the middle position from the spatial cue. Consequently, in rhythmic trials, the distance between the fifth (furthest) position and the

center of attention is divided in half, which results in maintaining a relatively high performance among all distances.

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Attention: Divided, models

Poster Session G > Attention: Divided, models > Poster G9

Measuring the saliency of an invisible visual feature and its interaction with visible features

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Tuesday 8:00 am - 10:00 am EDT

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A single object presented to one eye among many other identical objects presented to the other eye – an ocularity singleton – is salient to attract visual attention automatically. Saliency from ocularity contrast helps rapidly localize the foreground, especially in 3D visual scenes. However, unlike saliency by other feature dimensions, e.g., color (C) and orientation (O), uniqueness by ocularity (E, eye-of-origin) alone is perceptually invisible, making it difficult to be quantified. I.e., the reaction time to detect an ocularity singleton – RT(E) – remains unknown. Quantitative measures could help further investigate the interaction between saliency by ocularity and by other features, unfolding its neural mechanisms. In the current study, RTs were measured in a search task for a unique bar among many background bars with identical C, O and E features. The target bar was unique in either C or O alone, or unique simultaneously in two or three feature dimensions: CO, CE, EO, CEO. Importantly, with a quantitative model derived from the V1 Saliency Hypothesis (V1SH), which links saliency with neural activities of primate V1, RT(E) was then robustly calculated from RT(C), RT(O), RT(CO), RT(CE), RT(EO) and RT(CEO). Furthermore, by V1SH, whether RT(CE) is shorter than the RTs of the winner of a race model involving RT(E) and RT(C) reflects whether there are V1 neurons tuned conjunctively to both E and C – monocular neurons tuned to color – that contribute to saliency. Analogously, RT(EO) sheds light on monocular neurons tuned to orientation. We show that RT(CE) and RT(EO) are shorter than that of the race winner between single-feature RTs, suggesting a contribution by CE and EO neurons. However, this applies only to search among red rather than green background bars, suggesting an intrinsic color asymmetry for saliency interaction with ocularity.

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Poster Session G > Attention: Divided, models > Poster G10

Perceiving what is not there: Distractor intrusions accounted for by a computational model.

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Intrusions are intriguing errors in which subjects report that a feature of a distractor stimulus belonged to a target. These errors can occur in a specific type of rapid serial visual presentation (RSVP) experiment in which all stimuli carry two features. A stimulus-stream in such an experiment could consist of coloured letters and a typical task would be to report the identity of the stream's red letter. In this context, the feature that distinguishes target- from distractor-stimuli is called the key-feature (e.g. colour) and the feature that must be reported after each trial is called the response-feature (e.g. identity). Intrusions happen when, instead of the response feature of the target, that of a temporally neighbouring distractor is reported. For example, if the stream consisted of a blue S, a red E and a black P, and the task was to report the red letter, subjects would regularly report seeing the P as being red. Explanations of intrusions in previous research have typically only been informal in nature and the models available do not offer complete explanations. We present a computational model, which replicates response distributions of several experiments, for example after different empirical manipulations of key- & response-feature processing speeds. Our model additionally replicates counterintuitive

reaction-time patterns and very recent Event Related Potential findings associated with the N2pc and P3. We further demonstrate, empirically, that the N2pc and P3 are temporally correlated components, which supports a hypothesis implied by our model-architecture. We propose that illusory intrusions are the result of mis-bindings of stimulus features to working-memory encoding episodes. The likelihood of intrusions is dependent on the relative timing between key- and response-feature processing, which opposes models that proposed correct percepts and intrusions are processed in a qualitatively different manner. Thus, in our model, correct bindings are just “fortunate” conjunctions.

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Different Attention Allocation Determines Character of Visual Awareness

View Poster | Visit me in Gather.Town Osprey Room on Tuesday 8:00 am - 10:00 am EDT

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Deploying selective processing affords us the ability to identify and localize objects in a complex scene while non-selective processes such as extraction of global image properties and summary statistics allow for access to scene categories and ensemble representations. Together they give us a rich perceptual experience. Evidence suggests that the two types of processing do not work on the same time scale, but we still do not know whether the two interact and how. We employed an attentional blink paradigm examining how the temporary gap in visual awareness is modulated when performing two different tasks during rapid visual serial perception (RSVP). The stimuli were real scenes with the selective task requiring identification and localization to a quadrant of an object in the scene and the non-selective task requiring the categorization of the scene itself. In different blocks, observers are asked to perform two selective or non-selective tasks or two different combinations of these two tasks spaced at four different lags (300-1200 milliseconds) in the RSVP. There is a deep attentional blink when both tasks are selective with no full recovery even at lag 4. In contrast an attenuated blink with recovery at lag 2 when the selective task is preceded by a non-selective task. The pattern is different when the second task requires non-selective processing, with no blink for categorizing two scenes in succession and a deep blink that persists even at lag 4 when the scene categorization is preceded by object localization in a scene. There is a similar pattern of results when we use a much simpler field of dots stimuli. The findings show that sequentially allocating attention in a different manner to perform tasks that do or do not require selective processing results in interactions that indicate that selective and non-selective processing is not performed in parallel.

Poster Session G > Attention: Divided, models > Poster G12

Modeling the Geometry of Psychological Manifolds Using Continuously Changing Stimuli

View Poster | Visit me in Gather.Town Osprey Room on Tuesday 8:00 am - 10:00 am EDT

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In visual perception, the brain faces a difficult dimensionality reduction problem, with many nerve fibers converging to relatively few perceptual features. This is possible because meaningful structure in visual input lies on a lower-dimensional psychological manifold extracted by the visual system. However, while many cognitive processes are hypothesized to use geometric relationships between stimuli, there is no general method to assign psychological manifolds a geometry with an independently-verified notion of distance. To this end, we propose a model of the geometry of psychological manifolds that combines perceptual models with an attentional process that modifies discriminability according to context. These constraints induce a metric tensor that measures the length of curves on the manifold, including those corresponding to stimuli that change continuously through time. To investigate whether curve length corresponds to perceptual distance, we conducted an experiment (N = 39) comparing model predictions to judgements of the rate of change for dynamic stimuli with a one second duration. We first showed participants static, Gabor-like stimuli varying in spatial frequency and orientation, instructing them to place stimuli on a line according to the value of each dimension. We then presented pairs of changing stimuli and participants reported their confidence in which was changing faster in frequency or orientation with a slider. Using responses to static stimuli and assuming 80% attention to the cued dimension, difference in curve length predicted judgements for 36 of 39 participants (logistic GLM, >95% posterior probability). We then fit our model to all data and found it predicted judgements better than a flat approximation with one fewer parameter for 18 participants (approximate leave-one-out cross validation). These results

suggest that distance on a psychological manifold is a meaningful measure of subjective change. Additionally, our second analysis suggests that flat approximations of psychological manifolds are inappropriate for some participants.

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Poster Session G > Attention: Divided, models > Poster G13

Attentional bias for faces, not scenes: neural and behavioral evidence

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Social interactions form the foundation of human cultures and are critical to our survival. Since other people are dynamic and often unpredictable, our attention should be fixed on them by default. By contrast, since we are always within a spatial context (i.e., a scene), and since scenes are static and often predictable, our baseline attention to scene properties should be relatively low. Here, we provide evidence that visual attention is biased toward other people over scenes. In a functional magnetic resonance imaging (fMRI) experiment, a group of fifteen participants viewed blocks of scene and face images while making one of three judgements during each block: a category-specific judgment, one related to the central fixation cross, and another related to the outer edges of the image. We found a significantly greater reduction in response to scenes when attention was diverted away from the scene-specific features in the parahippocampal place area (PPA), compared to the minimal reduction in response to faces when attention was diverted away from the face-specific features in the fusiform face area (FFA). Next, in a behavioral experiment, two-hundred participants viewed a rapid serial visual presentation (RSVP) of intermixed scene, face, and object images, and then were asked to remember how many scenes, faces, or objects were displayed. Furthermore, half of the participants were told beforehand to attend to a specific stimulus type. We found that detection of scenes, faces, and objects were well above chance in the groups that were told to attend to a specific stimulus type. By contrast, in the groups that were not given such instructions, we found that scene and object detection fell to chance while face detection was unaffected. Taken together, these results provide neural and behavioral evidence that visual attention is biased towards other people compared to scenes.

Poster Session G > Attention: Divided, models > Poster G14

Meaningfulness affects performance in Navon task and Embedded Figures Test

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The Global Precedence Effect (GPE) is shown by improved or faster processing of global information over local information. For example, in compound stimuli where a larger shape is composed of smaller shapes, the large shape on the global level is processed faster and/or better than the smaller shapes on the local level. However, there is little evidence of a correlation between global/local processing tasks, such as Navon task that uses compound stimuli and the Embedded Figures Test (EFT) where target shapes are embedded within larger context figures. We hypothesize that the effect of meaningfulness on the GPE (the GPE is larger when Navon stimuli are meaningful) may also be shown in the EFT, providing evidence for a common mechanism for global and local processing in these tasks. Using compound stimuli (letters, objects, or non-object), we found better accuracy and faster response rates to meaningful stimuli (letters and objects). Although, the GPE was present in all three stimuli categories, it was reflected as higher accuracy at the global level in the object and the non-object stimuli and faster response to targets at the global level in the letter stimuli. We also found a higher accuracy rate in the EFT for meaningful and inversed meaningful than for non-meaningful stimuli, but faster responses to meaningful context figures compared to inversed meaningful and non-meaningful contexts. Furthermore, there was a significant correlation between performance on the Navon task with letter stimuli and the EFT with meaningful and inversed-meaningful stimuli but not with EFT non-meaningful stimuli. Focusing on separating GPE into global interference and advantage components to study their relationships with EFT respectively in future research may allow a more complete understanding of the relationship of meaning and global and local processing.

Predicting visual attention of human drivers boosts the training speed and performance of Autonomous Vehicles

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Autonomous driving agents deal with a complex skilled task for which humans train for a long period of time, relying heavily on their sensory, cognitive, situational intelligence, and motor skills developed over years of their life. Autonomous driving is focused on end-to-end learning of driving commands, however, perception and understanding of the environment remains the most critical challenge when evaluating situations. This is even more relevant in urban scenes, as they contain various distractions acting as visual noise that hinder the agent from understanding the situation correctly. Humans develop the skill of visual focus and identification of task-relevant objects from an early age. Information extracted from human gaze relevant to environment context can help the agent with this perception problem, injecting a wealth of information about human decision-making behaviour and helping agents focus on task-relevant features and ignore irrelevant information. We combine human gaze and features of task-relevant instances to enhance perception systems for autonomous driving. We use a virtual reality headset with built-in eye-trackers for participants (n=9) to use, providing us with human driving gaze data. Based on this, we build a human driving visual attention predictor. Our integrated object detector identifies relevant instances on the road while human visual attention prediction determines which objects are most relevant to the human driving policy. We present the results of using this architecture with imitation learning and reinforcement learning autonomous driving agents, and compare them with baseline end-to-end methods, showing improved performance, 28% in imitation and 11% in reinforcement learning, accelerated training and explainable behaviour with our approach. Our results highlight the potential of human in-the-loop approaches for autonomous systems which, as opposed to end-to-end approaches, allow us to make use of human skills in creating AI that closes the loop by augmenting humans in an efficient and explainable manner.

Development

The development of peak alpha frequency from infancy to adolescence and its role in visual temporal processing: A meta-analysis

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The dominant frequency of neural oscillations of the occipital, adult human brain is 8-12 Hz, denoted as the alpha frequency (Berger, 1929). These rhythms have been implicated in aspects of vision, specifically temporal processing (Samaha & Postle, 2015). In infants, a functional and topographical analog of the adult alpha rhythm was identified, but with a lower frequency range (Stroganova et al. 1999). While it is accepted that alpha increases over development, there is little work directly on the issue, and the precise developmental trajectory of peak alpha frequency (PAF) remains unclear. A more precise tracking will help constrain theories, specifically whether changes in PAF may underlie changes in temporal processing (Freschl et al., 2019, 2020). We conducted a meta-analysis to evaluate the development of PAF from infancy to adolescence (PAF, the frequency that exhibits maximum power within the alpha range, gives a more precise measure than band-power). Our abstract triage (keywords such as EEG, alpha, development, and typical) yielded 722 studies, and 378 met our criteria (i.e., reported occipital resting PAF in a typical population) for review. Each paper was reviewed by two trained members to ensure reliability. After full-text review, 35 studies were deemed relevant and PAF, along with other relevant information, was extracted for analysis. We conducted an asymptotic nonlinear regression on PAF as a function of age. This analysis revealed an increase in PAF from infancy (reaching 6.4 Hz at 6 months to 7.5 Hz at 36 months) to adolescence (reaching 9.4 Hz at 10 years to 10.3 Hz at 18 years), with an asymptote at 10.8 Hz, matching adult levels. These results pin down the precise developmental trajectory of PAF, which is consistent with our behavioral measures of the development of visual temporal processing (Freschl et al., 2019, 2020).

Acknowledgements: This project was supported by a grant from the National Institute of Mental Health (R21MH117787).

Poster Session G > Development > Poster G18

The Development of Oculomotor Suppression of Salient Distractors in Children

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There is now considerable evidence that adults can prevent attentional capture by physically salient stimuli via proactive inhibition. A key question is whether young children are also able to inhibit salient stimuli and orient towards task-relevant objects. Studies of classroom distractions, visual search, task switching, and attentional surround suppression found that children under the age of nine are unable to successfully inhibit distractors; a reaction time cost is present when irrelevant distractors are added to a display. The current study used eye-tracking to investigate whether 5-year-olds can suppress bottom-up attentional capture by a salient distractor. The destination of first saccades were used to assess attentional allocation by the salient distractor, providing a more direct index of attentional capture than prior developmental studies. Results demonstrated that children did not suppress eye movements to salient distractors like adults. That is, first saccades were equally likely to be directed to the singleton and nonsingleton distractors. Subsequent analyses indicated that children were eventually able to suppress the singleton distractor, but the time course of this suppression was delayed compared to adults. Altogether, the result demonstrated that children have some level of top-down control over visual attention, but this control is delayed compared to adults. Development of this ability may be related to executive functioning, which includes goal-directed behavior such as organized search and impulse control as well as preparatory and inhibitory cognitive functions.

Poster Session G > Development > Poster G19

A diffusion model decomposition of motion processing performance in children with dyslexia and related neural dynamics

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Children with dyslexia have elevated psychophysical thresholds in global motion tasks. However, threshold estimates conflate multiple processes so it is unclear which processing stages are altered in dyslexia. The drift-diffusion framework offers the possibility to model accuracy and response time distributions to decompose performance into separate processing components, which can then be linked to neural measures. Within this framework, the decision-making process is modelled as an accumulation of noisy sensory information towards one of two decision bounds. The main parameters are drift-rate (reflecting the rate of evidence accumulation), boundary separation (reflecting response conservativeness), and non-decision time (reflecting sensory encoding and response generation). Here, 50 children with a dyslexia diagnosis and 50 typically developing children aged 6 to 14 years judged the direction of coherent motion and Gaussian motion stimuli as quickly and accurately as possible. High-density EEG data were collected for most participants. Dyslexic children were slightly slower to respond for both stimulus types and were less accurate for Gaussian motion stimuli. In our pre-registered analyses, we fitted hierarchical Bayesian diffusion models to the data, both with and without controlling for differences in age. When controlling for differences in age, there was evidence for a reduced drift-rate in dyslexic children compared to typical children for both stimulus types (coherent motion: BF10=4.57; Gaussian motion: BF10=4.28). The evidence for differences in other parameters was inconclusive. We also identified a response-locked EEG component which was maximal over centro-parietal electrodes, which had lower amplitudes in dyslexic children compared to typically developing children. The results suggest that dyslexic children are slower to extract sensory evidence from motion stimuli.

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Poster Session G > Development > Poster G20

Dorsal stream receptive field development entails growing visual field coverage

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An important hallmark of the visual system are the receptive fields of its neurons, the area over which information is pooled from the visual field. We can measure this area from the population of neurons within a voxel during fMRI, referred to as the population receptive field (pRF). While recent work has begun to chart the development of these fundamental processing units within the ventral visual stream, how pRFs of the dorsal stream change with development has yet to be quantified. Here, in a set of n=18 children (5-12 years old) and n=23 adults we delineate the maps composing the human dorsal stream, beginning in V1 and ascending the intraparietal sulcus (IPS) from maps V3AB, IPS0 up to IPS1. While the volume and model fit of maps is developmentally stable, pRF properties of dorsal field maps undergo developmental changes, contrasting the stability previously measured within ventral field maps. Both the size and eccentricity of pRFs increase beginning in V3AB and age-related differences are largest in IPS1 where pRFs are 25% larger in adults compared to children ($t(29)=2.1$, $p=0.049$), and have 30% more eccentric pRF centers ($t(29)=2.5$, $p=0.017$). These developmental changes alter the way that the visual field is tiled by dorsal stream maps. From childhood to adulthood, the peripheral visual field becomes increasingly represented by dorsal stream maps, especially the ipsilateral visual field. This effect seems to increase as one ascends the dorsal stream, where eccentricities greater than 2 degrees of visual angle are 20-30% more densely covered by pRFs in adults compared to children within IPS1. Together, these findings demonstrate that the dorsal stream undergoes protracted development compared to ventral stream field maps and may suggest the fidelity of attention across the visual field may increase with development, which future studies manipulating attentional locus and scale can quantify.

Acknowledgements: Princeton Neuroscience Institute

Poster Session G > Development > Poster G21

Behavioral and neural analysis of the development of shape sensitivity in macaques

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In primates, shape discrimination improves in early development. Postnatal changes in the early visual pathway (primary visual cortex, V1) cannot account for this improvement. Thus, our ability to integrate lower-level information about forms, contours and curvatures into global shape percepts likely depends on areas downstream of V1. Neurons in mature V4 are sensitive to intermediate-level shape cues in ways that V1 neurons are not, but it is not known whether this selectivity is present in infancy. We have studied both behavioral and neurophysiological development of form sensitivity in 2 infant macaque monkeys, aged 5 to 12 mo. We used circular targets whose radii are modulated sinusoidally (radial frequency stimuli, RFS) to assess the development of form sensitivity in infant macaques. We tested the animals' ability to discriminate RFS with different frequencies of deformation (4, 8, 16 per circle) from circles as a function of depth of modulation using a 4-alternative oddity task. Behavioral sensitivity improved with age: sensitivity to higher frequency modulations improved relatively more. We also recorded neuronal responses to RFS from the same subjects at the same ages using two 96-channel "Utah" arrays, one in area V1 and one in V4. RFS responses in V1 were generally inconsistent, suggesting that they were driven primarily by local contrast. In V4, more sites showed consistent tuning for particular radial frequencies and amplitudes. We used linear discriminant analysis to determine each population's ability to discriminate between a circle and RFS stimuli. As expected, the V4 neuronal population was more selective to RFS than the V1 population. We also found that relative sensitivity for different radial frequencies was similar for behavior and the population of V4 neurons, suggesting that this kind of shape selectivity may reflect the activity of area V4 even in infancy.

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Poster Session G > Development > Poster G22

Analogous development of local/global preference in vision and touch.

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Several studies have investigated local/global perception in vision, but less attention has been given to touch. To get better insights into the mechanisms of local/global perception, we here explore its developmental path and compare performance across vision and touch. Particularly, we focus on the impact of element size and density on local/global perception. Forty-four typically developing individuals covering an age-range from 6.01 to 26.48 years completed a similarity judgment task in vison and touch. The 3D printed stimuli were made out of local elements (squares or triangles) that were arranged to form a global shape (square or triangle). Local and global shape could either be consistent or inconsistent. The local elements of the stimuli had three possible sizes (3.5, 5.3 or 9 mm) while the size of the global shape ranged from 1.99 to 3.35 cm. In the critical test trials, participants had to say whether the inconsistent target stimulus was more similar to either the consistent square or the consistent triangle. Responses were categorized as “global” when the chosen stimulus had the same global configuration as the target and “local” otherwise. Results showed that the proportion of global responses increased with age in both vision and touch. For stimuli with large local elements, however, there was no global preference across all ages in touch. Importantly, the correlation between vision and touch of the proportion of global responses increased with age. These findings indicate that the coordination between vision and touch for local/global perception develops with age. This might indicate that they share the same or similar mechanisms developing with age.

Poster Session G > Development > Poster G23

Neural measurements of sensitivity to contrast and texture naturalness in developing macaques

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Performance on a variety of visual tasks improves across early development. By identifying a neural substrate for this improvement, we can improve our understanding of visual function. Previous measurements of spatial contrast sensitivity, made in the LGN, V1, and V2, could not account for behavioral improvements. We wondered whether a stimulus feature that is more tightly linked to a specific neural locus could help us target developmental improvements. The model of Portilla and Simoncelli generates textures matched in spectral content, but varying in the strength of their naturalistic image statistics. Importantly, neuronal sensitivity to this “naturalness” is not seen in adult area V1, but is seen in adult areas V2 and V4. Using 96-channel multielectrode arrays, we recorded neural responses from areas V1, V2 and V4 from macaques at six and twelve months of age both to bandpass-filtered noise stimuli varying in contrast (as well as spatial frequency and orientation), and to texture stimuli varying in naturalness. We used standard classification techniques to measure both spatial contrast and texture naturalness sensitivity from recorded spiking activity, and we interleaved behavioral measurements from the same animals for comparison. Neural sensitivity to both contrast and naturalness was similar across age. While contrast sensitivity was similar between areas, naturalness sensitivity was greater in area V4 than in V2, as we and others have found in data from adults. These results suggest that the hierarchical processing of texture sensitivity observed in adults is established early in development.

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Poster Session G > Development > Poster G24

Early emergence and later development of face, scene, and object regions revealed by natural vision

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High-level visual cortex contains a stereotyped set of regions specialized for processing faces, scenes, and objects. How do these regions develop? Answering this question has proven challenging, given the difficulty of collecting fMRI data from young children – a problem exacerbated by reliance on relatively unengaging paradigms designed for adults. Here we addressed this challenge by studying responses to a short, engaging, animated movie depicting natural visual experience, which allowed high-quality data collection from a large sample (N=122) of children age 3-12 years. We first developed a method for defining face, scene, and object regions using movie data, and confirmed that this method accurately identifies subject-specific regions in adults. We then studied how adult regions responded during the video, and found that the content of movie events eliciting peak responses reflected the well-known selectivity of each region for faces, scenes, or objects. Adults also showed stronger interregional correlations between regions with more similar functions (e.g., two scene regions) than regions with distinct functions (e.g., a face and a scene region). Having characterized responses in adults, we next tested for this same functional organization in children. Remarkably, adult-like function was already detectable across face, scene, and object regions by just 3 years of age, with children showing peak responses to similar movie events, and similar patterns of interregional correlations, as adults. Later in development, the magnitude of responses to peak events continued to increase, with individual regions following distinct trajectories. For example, the fusiform face area showed relatively little change across childhood, whereas the posterior superior temporal sulcus showed clear evidence of protracted developmental change. Taken together, these results reveal that adult-like function emerges in face, scene and object regions within the first three years of life, yet continues to be refined along distinct trajectories in specific regions across childhood.

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Poster Session G > Development > Poster G25

Innate organization of the human brain

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The human brain is composed of a multitude of areas with distinct roles in mental function; these regions connect and interact with a set of other brain regions, forming functional networks which are the basis of large-scale information processing in the brain. These functional networks can be reliably identified in human adults as well as other species, and small individual differences in connectomes may contribute to individual differences in behavior. Here, we aim to characterize these functional networks in neonates scanned within one week of life. We use unsupervised learning to uncover underlying patterns in resting-state functional connectivity data from a large cohort of neonates (N = 267 full-term infants from the Developing Human Connectome Project). First, we present the neonate networks determined by optimal solutions in terms of fit and replicability. We found symmetrical and hierarchical networks associated with sensorimotor, visual, default mode, ventral attention, and high-level sensory areas. Second, we explored the inter- and intra-subject variability of these networks and found that some networks (e.g. sensorimotor) had low inter-subject variability whereas others (e.g. dorsal attention) had high inter-subject variability while maintaining high intra-subject consistency. Third, we compared the neonate networks to those in adults (Yeo et al., 2011) and found similarities with sensorimotor, visual, dorsal and ventral attention, and default mode networks. However, frontoparietal and limbic networks found in adults were not discernible in neonates. Finally, we investigated differential gene expression, determined by the Allen Human Brain Atlas, as a potential explanation for the emergence of these distinct networks, and quantified within and between network similarity. These results suggest the basic network structure present in adults also exists at birth, but some important differences, particularly in association cortex, suggest a role for maturation and experience in developing adult-like functional brain organization.

Poster Session G > Development > Poster G26

The shape skeleton supports one-shot categorization in human infants

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Artificial neural networks (ANNs) require enormous amounts of data to learn object categories. By contrast, humans can form a category from just one exemplar. This feat of categorization is integral to decision making but, surprisingly, remains poorly understood. Here we tested whether an invariant object structure—namely, an object's internal skeleton—supports one-shot object categorization in human infants, a population with limited object experience. Across two experiments, 6- to 12-month-olds (Mage = 9.29 months; N = 82) were habituated to a single, never-before-seen object. They were then tested with objects that differed from the habituated object in their surface contours and either matched or mismatched in their skeletal structure. To further constrain the mechanisms implicated in this task, we compared infant performance to computational models of object recognition that do not incorporate a skeletal algorithm. These included top-performing recognition models (ResNet trained on ImageNet or Stylized-ImageNet), recurrent models designed to approximate recognition processes of the primate visual system (CorNet-S), as well as models designed to approximate the visual experience and learning mechanisms of infants (self-supervised ResNext trained on infant headcam videos). Importantly, these models were tested using procedures comparable to infants. Because habituation/dishabituation can be conceived as a measure of alignment between the stimulus and the infant's internal representation, we tested ANNs by incorporating an autoencoder onto each model and measuring the error signal across habituation/dishabituation phases. We found that only infants were able to categorize novel objects from one exemplar. By contrast, ANNs failed to categorize objects under the same conditions. Qualitatively similar results were found when models were tested using conventional classification techniques. Taken together, these findings suggest that single exemplar categorization reflects an early-developing sensitivity of the human visual system to perceptually invariant object structure.

Counting sheep: Perceptual narrowing of other-species faces in infant fMRI

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Infants have less expertise than adults in perceiving human faces, but this reduced specialization trades off with a greater ability to distinguish individuals of other species. These differences between infants and adults diminish by the end of the first year. How does the brain support such perceptual narrowing? Developmental changes in the tuning of sensory cortex may be responsible, affecting which bottom-up features are available for perception. We test this hypothesis using an fMRI repetition suppression design in young infants, older infants, and adults. Face-selective regions tend to show reduced BOLD activity when the same face identity is viewed repeatedly compared with when different identities are viewed, suggesting that these regions are tuned to individual identities. We applied this adaptation logic while participants viewed short blocks containing human faces, sheep faces, or scenes. In the face conditions, half of the blocks presented the same identity multiple times sequentially (Repeat) whereas the other half presented a matched number of faces each from a unique identity (Novel). The difference in BOLD activity for Novel minus Repeat blocks provides an index of repetition suppression. We expected adults to show more repetition suppression than infants for human faces, but infants to show more repetition suppression than adults for sheep faces. Data collection is ongoing toward planned sample sizes, but we conducted preliminary analyses with available data. Consistent with our predictions, adults but not younger or older infants showed repetition suppression for human faces in fusiform and occipital face areas. This suggests that the tuning of visual regions for human faces emerges on a more protracted timescale than behavioral discrimination. Inconsistent with our predictions, although younger infants showed repetition suppression to sheep faces in face-selective regions, so too did older infants and adults. These preliminary results motivate further work exploring the mechanisms of perceptual narrowing.

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Anatomical changes to primary visual cortex in the congenital absence of cone input

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Achromatopsia (ACHM), a rare autosomal recessive visual disorder, is characterized by a loss of cone signal transduction. This results in a congenital absence of visual input from cone photoreceptors, which dominate the foveal retina, to primary visual cortex, potentially affecting the integrity of visual cortical macrostructure. As current retinal gene augmentation therapies rely on intact cortical anatomy, the aim of this multi-centre study was to determine the status of primary visual cortex in this patient population. We used high resolution T1-weighted 3T MRI scans (1mm isotropic resolution) and surface-based morphometry to compare cortical thickness, surface area and grey matter volume in primary visual cortex in 15 ACHM participants and 42 healthy controls within three regions-of-interest (foveal: 0-2deg, parafoveal: 2-4deg, paracentral: 4-8deg). Grey matter volume was significantly reduced only in the paracentral representation ($\Delta R2 = 8.8\%$; ($F(1,50) = 5.398$, $p = .024$), while surface area was reduced across foveal ($\Delta R2 = 4.2\ \%$; $F(1,50) = 5.651$, $p = .021$), parafoveal ($\Delta R2 = 5.5\ \%$; $F(1,50) = 4.846$, $p = .032$) and paracentral representations ($\Delta R2 = 17.6\%$; $F(1,50) = 12.851$, $p = .001$) of primary visual cortex. In contrast, a thickening of visual cortex was found only in the foveal region representing the absolute scotoma ($\Delta R2 = 7.4\%$; ($F(1,50) = 6.173$, $p = .016$). These findings are comparable to more widespread anatomical differences reported in other congenital visual disorders, indicating a possible common mechanism underlying changes during cortical development. Overall, these results suggest that early intervention is favourable to counteract any developmental changes caused by the missing sensory input in ACHM.

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Drawing from the Mind's Eye: The Development of Drawing in Sight-Restored Children.

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Drawing is a highly multimodal process and its developmental trajectory broadly progresses from drawings that reflect mental models to recreations of visual perception. To tease apart the relative roles of the sensory systems involved in the development of drawing, one requires a model in which input is withheld from each system independently and then re-introduced when the other systems have matured. We have the unique opportunity to do this by studying visual development and skill acquisition in children born with curable blindness in rural India. After providing them with sight-restoring surgery, we longitudinally tested these children to measure multiple aspects of graphic production, including copying shapes and drawing known objects. We found that despite the presence of language to support shape recognition and age-appropriate motor control prior to treatment, sight onset itself did not immediately lead to improved copying but did allow for the quick onset of well-developed tracing skills. Within 6-12 months following treatment, performance rapidly improved and contained many milestones reported in the typically developing trajectory, although aspects of tactile-shape exploration and production were often qualitatively different between the patient and control cohorts, both before and after sight-onset. Additionally, when children were asked to draw familiar objects from memory, all sight-restored children's drawings were far below age-level initially, beginning at the classic 'scribble' and 'pre-

schematic' developmental stages of drawing from mental models (e.g. a tadpole representing a person, an architect's view of a house). While the onset of visual experience led some children to transition to the 'schematic' stage, where they drew what they saw (drawing from perception), most children stayed "stuck" with drawing what they knew (drawing from mental models). Overall, our data provides novel insights into cognitive models of drawing, and their importance for understanding the development of internal representations.

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Poster Session G > Development > Poster G30

The ontogeny of spatial perception in sighted and blind infants

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Congenitally blind infants develop in a perceptual environment which not only lacks visual input but is also deprived of the influences of vision on the intact senses such as in crossmodal calibration and the mapping of the senses to external spatial coordinates. Comparing early spatial representations in blind and sighted infants, we elicited manual orienting responses to auditory and tactile stimuli presented on infants' hands, manipulating arm posture to examine the frames of reference used for localisation. The sighted infants oriented to auditory cues in audiotactile presentations, and used an external spatial code when locating touches (they showed a crossed hands deficit [6]). The blind infants oriented to tactile cues in audiotactile presentations and used an anatomical spatial code for locating touches, notably showing improved tactile localisation than the sighted participants in the crossed hands condition. Both the sighted and the blind infants demonstrated improved localisation when auditory stimuli were presented at the same time and on the same hand as tactile stimuli, but the blind infants showed a weaker multisensory gain. The blind infants' responses to touches at the expense of auditory cues indicates an impairment of auditory localisation, leading to a spatial bias to anatomical rather than external coordinates. The finding of multisensory gain across blind and sighted infants demonstrates multisensory integration. This shows that spatial localisation can be enhanced in blind infants by providing spatially congruent stimulation across audition and touch, a finding which bears important implications for approaches to early intervention.

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Poster Session G > Development > Poster G31

Performing visual tasks by children with amblyopia.

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Purpose: Amblyopia–the condition when the observer sees nothing and the patient very little. Eye-hand coordination develops gradually in infancy and continues through to pre-school age, so it is important to develop the child's motor skills through various activities and games during this period. Eye-hand coordination, also known as visual motor coordination, is the simultaneous interaction between the eyes and hands that results in a response to visual information captured by the visual system. Children with amblyopia are known to have impaired visual motor skills, which limits the child's daily activities and perception of the world around them. Children may have difficulty perceiving visual information, moving around in space, which affects their academic performance. Methods: There were 30 participants: 15 participants with amblyopia and 15 participants without vision problems who are divided into 3 age groups–5, 6 and 7 years. Twelve standard tasks, often used in kindergartens, were used in the work. The visual tasks were divided into different categories and was evaluated, as well as visual acuity of amblyopic eye and stereopsis, before and after the treatment. Results: The task for all children was the same, to complete all tasks as quickly and accurately as possible.

Amblyopia has the greatest impact on visual tasks that require coordinated eye-hand interaction. In tasks that require drawing, finding and matching objects of the same shape, the completion time is independent of the presence of amblyopia. In tasks where the correct colour has to be indicated, the completion time of all items depends on age. Conclusions: If amblyopia has not been treated successfully in the childhood, it can cause the constant visual disturbance. It is important to assess how amblyopia affects motor skills and visual perception in pre-school children, as visual perception is important for children of this age for further self-development.

Object Recognition: Neural mechanisms

Poster Session G > Object Recognition: Neural mechanisms > Poster G41

Conservation across individuals of cortical crowding distance in human V4

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Crowding distance and size of cortical visual areas vary several-fold across individuals. Multiplying perceptual crowding distance (deg of visual angle) by cortical magnification (mm of cortex per deg) yields cortical crowding distance in mm. Cortical crowding distance is conserved across eccentricity in V1, V2, V3 and hV4 (Pelli, 2008). It is approximately conserved across orientations of the axis of flankers in hV4 but not V1, V2, and V3 (Zhou et al., VSS, 2018). Here we assess conservation across individuals. For each visual area we test the hypothesis that cortical crowding distance (mm) is conserved across individuals, despite individual variations in map size (mm2) and crowding distance (deg). With fMRI, we measured retinotopic maps in 26 observers and manually defined the boundaries of V1, V2, V3 and hV4. For each of these regions we calculated surface area in mm2. In the same individuals we measured crowding distance at 12 locations (4 meridians, 3 eccentricities) of the visual field. We use these psychophysical data to build a model of crowding distance from which we derive the Bouma factor, B, (slope of crowding vs eccentricity) for each individual subject. Conservation predicts that the Bouma factor scales inversely with the square root of area. Combining fMRI with psychophysics revealed that cortical crowding distance is approximately conserved in hV4 but not in V1, V2, or V3. Specifically, in hV4 the Bouma factor scaled nearly with the inverse square root of surface area predicted by conservation (exponent of –0.55, 95% CI [-0.2 -0.9]): Observers with smaller hV4 tend to have a larger Bouma factor and thus need a larger target-flanker spacing to identify the crowded target. The hV4 surface area explained ~30% of the variance in Bouma factor across observers. More work is needed to understand the sources of the remaining variance.

Acknowledgements: The research was supported by NIH grants R01EY027964

Poster Session G > Object Recognition: Neural mechanisms > Poster G42

Contribution of receptive field center and surround to repetition suppression in macaque visual area V2

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Monkey inferotemporal cortex (ITC) neurons respond with declining strength to repeated presentations of relatively large and complex natural images. This phenomenon – repetition suppression – has often been assumed to arise at the level of ITC because ITC neurons possess the large receptive fields and sophisticated stimulus selectivity necessary for recognizing the image as a repetition. It has been recently discovered, however, that neurons in V2 exhibit repetition suppression under conditions identical to those in studies of ITC. This raises the question: How do V2 neurons, with classical receptive fields encompassing only a small fraction of the image, recognize it as a repetition? One possibility is that they are sensitive to repetition of image content not only in the classical receptive field but also in the receptive field surround. To assess this possibility, we monitored neuronal responses to sequential displays in which we controlled independently the repetition of elements in the classical receptive field and in the surround. Each stimulus consisted of a disk scaled to and centered on the classical receptive field and an adjoining annulus (8° outer diameter). The disks and annuli were taken from different natural scenes. The display on each trial consisted of a prime, a delay, and a probe,

each 300 ms in duration. We found that repetition of the central disk was sufficient to produce repetition suppression but that suppression was enhanced by simultaneous repetition of the annulus. Suppression arising from repetition of the annulus occurred in a relatively late phase of the response, in accordance with the idea that it might have been mediated by horizontal connections in V2 and/or feedback from downstream areas. Overall, this work demonstrates that sensitivity to content outside the classical receptive field contributes to the image specificity of repetition suppression observed in V2 neurons to large natural images.

Acknowledgements: Grant Support: NIH RO1 EY024912

Poster Session G > Object Recognition: Neural mechanisms > Poster G43

Learning a model of shape selectivity in V4 cells reveals shape encoding mechanisms in the brain

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The mechanisms of local shape information transformation from V1 to more abstract representations in IT are unknown. Studying the selectivities in intermediate stages of transformation suggest plausible mechanisms. For example, Pasupathy and Conner [1] studied Macaque V4 responses to convexities and concavities. They found that these neurons are selective to boundary configurations at a specific position in the stimulus, for example, a convexity adjacent to a concavity. Although such investigations reveal intermediate shape representations in the brain, they often do not suffice in capturing complex and long-range interactions within the receptive field due to imposing priors on tunings, e.g., fitting a single Gaussian to neuron responses. Here, we propose a learning-based approach that eliminates the need for such strong priors. Specifically, we investigate shape representation in Macaque V4 cells and formulate shape tuning as a sparse-coding problem according to previous findings of V4 neurons[1]. We emphasize that our goal is not to find a mapping from the stimulus to V4 responses but to study how V4 neurons combine responses of curvature-selective V2 cells to achieve their reported part-based selectivities. To this end, our proposed model takes responses of simulated curvature-selective V2 cells as input by combining two previously introduced hierarchical models [2,3]. With simulated curvature signal as input, our algorithm learns a sparse mapping to V4 responses that reveals each Macaque V4 cell's tuning and the mechanism by which the tuning is achieved. Our model captures sophisticated interactions within the receptive field from neuron responses. Our results on V4 shape representations confirm long-range interactions between components of a larger shape, providing a better understanding of shape encoding mechanisms in the brain. [1] A. Pasupathy et al. J. of Neurophysiology(2001) 86:5, 2505-2519. [2] A. J. Rodríguez-Sánchez et al. PLoS One (2012) 7(8), e42058. [3] P. Mehrani et al. (2019) arXiv:1901.03201.

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Poster Session G > Object Recognition: Neural mechanisms > Poster G44

Measuring crowding in a hundred people

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Surrounding an object by similar clutter makes it unrecognizable, a phenomenon called "crowding". Crowding varies greatly across the visual field and across individuals. To better understand the individual differences, we measured radial crowding distance (i.e. "critical spacing") and acuity across the visual field in 116 observers using letter stimuli. We compared crowding and acuity, and we assessed crowding's dependence on eccentricity along several meridians. Fitting the Bouma Law — crowding distance grows linearly with radial eccentricity — we find that the Bouma factor (slope of crowding distance vs. eccentricity) is conserved along each meridian, but varies across meridians, showing three asymmetries: crowding distance and Bouma factor are 14% smaller in the right than left meridian, 10% smaller in lower than upper meridian and 35% smaller on the horizontal than vertical meridian. Previous studies reported the advantage of the lower and horizontal meridians; the left-right asymmetry is new. Power analysis indicates that a minimum of 30 observers is required to detect this effect, more than past studies tested. Taking into account meridional and individual differences we built a model of log crowding distance that explains 73% of the variance (leave-1-condition-out cross-validation). Furthermore, we find that the correlation between crowding and acuity is strongest in the fovea R=0.51 and drops to R=0.27 at 5 deg eccentricity. This indicates that clinical characterization of vision may need to assess both acuity and crowding. In sum, our crowding survey confirms the Bouma law, and characterizes variation of the Bouma factor across meridians and observers.

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Poster Session G > Object Recognition: Neural mechanisms > Poster G45

Neural correlates of configural processing of faces and words: Domain-general or domain-specific?

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While configural processing has been observed for faces and words, it remains unclear whether similar neural correlates support such processing for these visually distinct categories. Specifically, since selectivity for faces and words is often observed in different focal regions in the occipitotemporal cortex (e.g., right fusiform 'face' area (RFFA) for faces, and left visual word form area (LVWFA) for words), to what extent configural processing of the specific category is observed in the respective category-selective regions? In Experiment 1, Chinese participants (N=20) viewed faces and Chinese characters in either intact or exchanged formats (with top and bottom parts switched). FMRI results revealed that in RFFA1, RFFA2, and LVWFA, defined at the individual-level in a separate localizer, RFFA1/RFFA2 were sensitive to configural information of faces, with significantly stronger activations for intact than exchanged formats (p's<.001). In contrast, sensitivity to configuration of Chinese characters was observed in LVWFA, but with weaker activations for intact than exchanged formats instead (p=.003). In Experiment 2, native English speakers who were non-Chinese readers (N=20) viewed English words and Chinese characters in either intact and exchanged formats (with left and right parts switched for English words). Similar to the results with Chinese participants viewing Chinese characters, weaker activations were found in LVWFA when native English speakers viewed intact than exchanged English words (p<.001), but no differences were found across the two formats of Chinese characters (p>.27). Additionally, RFFA1 showed stronger activations for intact than exchanged English words (p<.05), similar to the effects of faces in right FFA1 in Experiment 1. Together, both experiments revealed different patterns of configural effects for RFFA1/RFFA2 and LVWFA. Moreover, LVWFA appears to support expertise-related configural processing of words only, suggesting a domain-specific mechanism, while RFFA1 supports configural processing of faces, and of words in the absence of faces, suggesting a domain-general mechanism.

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Poster Session G > Object Recognition: Neural mechanisms > Poster G46

Representational structure for letters is found throughout ventral visual cortex and matches human perception

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Does ventral visual cortex contain separate regions with specialized representations for specific categories of stimuli, or is there a general representational space for all categories shared across regions? Here, we examined this long-standing question by considering representations of visually-presented letters, which are known to drive selective responses in a circumscribed region of inferotemporal cortex. Using fMRI, we measured cortical responses to each lowercase letter individually, across twenty fonts, in 14 participants. We conducted a searchlight analysis comparing the two halves of the dataset, revealing moderately reliable RDMs for letters extensively throughout ventral visual cortex. We even found RDMs with moderate split-half reliability in regions selective for other categories (fusiform face area: left:

ρ=0.38, right: ρ=0.53 and parahippocampal place area: left: ρ=0.43, right: ρ=0.43). Do any of these reliable brain regions have representational structure corresponding to behavioral signatures of letter similarity? To measure the perceptual similarity of letters, we asked participants (n=517) to categorize single letters rapidly with a yes/no response (e.g. is this an “a”?), where the time it took to reject a letter was considered a measure of its similarity to the target. We found that regions throughout ventral visual cortex, including bilateral FFA and PPA, all correlated with the behaviorally-measured similarity of letters. Additionally, extensive brain-behavior correlations were found when letter similarity was measured with a second behavioral task, visual search (n=222). These results demonstrate that the behaviorally-measured representational geometry of letters is found throughout ventral visual cortex, rather than being isolated to a specific region. Broadly, these findings join previous research (Cohen et al, 2016; Prince & Konkle, 2020) suggesting that inferotemporal cortex contains an integrated feature space, with tuning relevant to all kinds of visual stimuli evident throughout this cortex.

Acknowledgements: NSF CAREER: BCS-1942438

Poster Session G > Object Recognition: Neural mechanisms > Poster G47

The relative coding strength of color and form in the human ventral visual pathway and convolutional neural networks

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Color and form information are encoded throughout the human ventral visual hierarchy, and throughout the different processing layers of many convolutional neural networks (CNNs). However, these properties are often studied in isolation, leaving open the question of how they are encoded together. Here, we examine the relative coding strength of these two features in brain regions and CNN layers (i.e., how strongly each influences the representational geometry), and how this changes over the course of processing (i.e., from lower to higher visual regions and from lower to higher CNN layers). We collected fMRI responses from human V1, V2, V3, V4, and LOC to stimulus sets that each varied in their color and form features. We also collected the responses of multiple ImageNet-trained CNNs to the same stimuli. In Experiment 1, when orientation, a simple form feature, was varied, we found that color coding became increasingly dominant relative to form over the course of processing. By contrast, in Experiment 2, when curvature, a more complex form feature, was varied, form coding became increasingly more dominant relative to color over the course of processing. We observed qualitatively similar results in both the human brain and in CNNs, indicating that, relative to color coding, orientation coding decreases and curvature coding increases during visual processing. That said, despite similarities in the relative coding strengths of these features, CNNs and the human brain differed in how the absolute coding strengths of these features evolve during processing. Additionally, these similarities disappear in untrained CNNs, suggesting they arise from training the networks to recognize objects. Together, these results unveil how color and form jointly shape the visual representational space in both the human visual system and CNNs over the course of processing.

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Poster Session G > Object Recognition: Neural mechanisms > Poster G48

THINGS-fMRI/MEG: A large-scale multimodal neuroimaging dataset of responses to natural object images

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A detailed understanding of visual object representations in brain and behavior is fundamentally limited by the number of stimuli that can be presented in any one experiment. Ideally, the space of objects should be sampled in a representative manner, with (1) maximal breadth of the stimulus material and (2) minimal bias in the object categories. Such a dataset would allow the detailed study of object representations and provide a basis for testing and comparing computational models of vision and semantics. Towards this end, we recently developed the large-scale object image database THINGS of more than 26,000 images of 1,854 object concepts sampled representatively from the American English language (Hebart et al., 2019). Here we introduce THINGS-fMRI and THINGS-MEG, two large-scale brain imaging datasets using functional magnetic resonance imaging (fMRI) and magnetoencephalography (MEG). Over the course of 12 scanning sessions, 7 participants (fMRI: n = 3, MEG: n = 4) were presented with images from the THINGS database (fMRI: 8,740 images of 720 concepts, MEG: 22,448 images of 1,854 concepts) while they carried out an oddball detection task. To reduce noise, participants' heads were stabilized and repositioned between sessions using custom head casts. To facilitate the use by other researchers, the data were converted to the Brain Imaging Data Structure format (BIDS; Gorgolewski et al., 2016) and preprocessed with fMRIPrep (Esteban et al., 2018). Estimates of the noise ceiling and general quality control demonstrate overall high data quality, with only small overall displacement between sessions. By carrying out a broad and representative multimodal sampling of object representations in humans, we hope this dataset to be of use for visual neuroscience and computational vision research alike.

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Poster Session G > Object Recognition: Neural mechanisms > Poster G49

Two distinct networks containing position invariant representations of actions in the human brain

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Humans can recognize others' actions in the social environment. This recognition ability is tolerant to drastic variations in the visual input caused by the movements of people in the environment. What neural underpinnings support this position-tolerant action recognition? In the present study, we aimed to identify regions in the brain that contain position-tolerant representations of actions and explore the representational content of these regions. We recorded fMRI data from twenty-two subjects while they observed video clips of ten different human actions in Point Light Display format. Each stimulus was presented in either the upper or the lower visual fields. We used multivoxel pattern analysis and a searchlight technique to identify brain regions that contain position tolerant action representation. In a generalization test, linear support vector machine classifiers were trained with fMRI patterns in response to stimuli presented in one position and tested with stimuli presented in another position. Results showed above-chance classification in the left and right lateral occipitotemporal cortex, right inferior intraparietal sulcus, and right superior intraparietal sulcus. To investigated the representational content of these regions, we constructed two models, one based on the movement of the body parts and another based on the similarity ratings obtained from an independent behavioral experiment. In a multiple regression analysis, we used these models to predict the cross-position decoding accuracies for each ROI. Results showed that the objective body-part model was a better predictor for the accuracies in the parietal regions, while the model based on the subjective ratings of similarity was a better predictor of the accuracies in the occipitotemporal regions. These results suggest the existence of two distinct networks containing abstract representations of human actions.

Poster Session G > Object Recognition: Neural mechanisms > Poster G50

Maps of object animacy and aspect ratio in human high-level visual cortex.

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A recent study by Bao and colleagues (Nature 2020) revealed a series of three topographic maps in macaque inferotemporal cortex (IT) that respond according to the animacy and aspect ratio of viewed objects. This could suggest that face-, body- and scene-selective regions of IT are districts of a larger continuous map whose organizing principles are based on visual properties of the stimulus. Such representational spaces were also found in a convolutional neural network trained to classify objects, suggesting a similar encoding of objects across the biological and artificial visual systems. However, these maps have not yet been identified in the human brain. Using fMRI, we measured the neural response in human IT to the same stimuli used in the macaque experiment. A localizer was designed using four object conditions: animate spiky, animate stubby, inanimate spiky and inanimate stubby. In 5 out of 6 subjects, we found regions of IT that were significantly more responsive to each condition than other conditions, potentially consistent with an animacy / aspect ratio organization in human IT. Next, we asked whether these regions were clustered in a series of three repeating maps of object space arranged along the posterior-anterior axis of IT, as was found in macaque. In 5 out of 6 subjects, we identify at least one cluster of regions that could indicate a map of object space. However, no subject clearly exhibited a series of three maps along IT. Taken together, these results suggest that the topographic organization of human IT may be accounted for by one or more maps of object space based on animacy and aspect ratio.

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Poster Session G > Object Recognition: Neural mechanisms > Poster G51

Putting people in context: N190 responses to bodies in natural scenes

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The N190 is a body-sensitive ERP component that responds to images of human bodies in different poses. In natural settings, bodies vary in posture and appear within complex, cluttered environments, frequently with other people. In many studies, however, such variability is absent. How does the N190 response change when observers see images that incorporate these sources of variability? In two experiments (N=16 each), we varied the natural appearance of upright and inverted bodies to examine how the N190 amplitude, latency, and the Body-Inversion Effect (BIE) were affected by natural variability. In Experiment 1, we varied the number of people present in upright and inverted naturalistic scenes such that only one body, a subitizable number of bodies, or a “crowd” was present. In Experiment 2, we varied the natural body appearance by presenting bodies either as silhouettes or with photographic detail. Further, we varied the natural background appearance by either removing it or presenting individual bodies within a rich environment. Using component-based analyses of the N190, we found that the number of bodies in a scene reduced the N190 amplitude, but didn't affect the BIE (Experiment 1). Naturalistic body and background appearance (Experiment 2) also affected the N190, such that component amplitude was dramatically reduced by naturalistic appearance. To complement this analysis, we examined the contribution of spatiotemporal features (i.e., electrode × time point amplitude) via SVM decoding. This technique allows us to examine which timepoints across the entire waveform contribute the most to successful decoding of body orientation in each condition. This analysis revealed that later timepoints (after 300ms) contribute most to successful orientation decoding. These results reveal that natural appearance variability affects body processing at the N190 and that later ERP components may make important contributions to body processing in natural scenes.

Poster Session G > Object Recognition: Neural mechanisms > Poster G52

GLMsingle: a turnkey solution for accurate single-trial fMRI response estimates

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Recent massive fMRI data collection efforts – e.g., the Natural Scenes Dataset (NSD; Allen et al., VSS 2020) and

BOLD5000 (Chang et al., 2019) – have measured high-resolution brain responses to tens of thousands of naturalistic visual stimuli. These efforts enable novel, data-hungry analyses that can more finely characterize visual representations and test theories of visual function. However, one challenge for such experiments is that fMRI measurements typically suffer from low signal-to-noise ratio and a high degree of signal overlap across trials. We introduce GLMsingle, a scalable, user-friendly tool for the accurate estimation of single-trial fMRI responses. Requiring only BOLD time-series data and a design matrix as inputs, GLMsingle integrates three techniques designed to improve the accuracy of trial-wise GLM beta estimates. First, for each voxel, a custom hemodynamic response function (HRF) is identified from a library of candidate functions. Second, the selected HRFs are used in a cross-validated GLM in order to derive a set of noise regressors from voxels unrelated to the experimental paradigm (“GLMdenoise”; Kay et al., 2013). Third, to mitigate the effects of signal overlap, beta estimates are regularized on a voxel-by-voxel basis using ridge regression ("Fracridge"; Kay & Rokem, 2020). Validation on both NSD and BOLD5000 reveals that GLMsingle substantially improves the signal-to-noise ratio of beta estimates across visually-responsive cortex in all participants. Furthermore, we find that GLMsingle meaningfully impacts three higher-level aspects of the data relevant for neuroscientific analyses: it improves the decorrelation of signal estimates between trials that are nearby in time, it enhances the representational similarity between participants within and across datasets, and it boosts one-versus-many decodability of visual stimuli that overlap between NSD and BOLD5000. Together, these results indicate that GLMsingle can help improve the quality of existing or future neuroimaging datasets that sample brain activity across many experimental conditions.

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Poster Session G > Object Recognition: Neural mechanisms > Poster G53

Odors assist the categorization of ambiguous visual stimuli

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Visual categorization is the rapid and automatic ability to provide a similar response to different exemplars of a single category despite widely variable sensory inputs. Whether visual categorization is solely visually-driven or can be influenced by other sensory modalities remains unclear. Here we test whether odor contexts can modulate visual categorization in humans, expecting that congruent odors facilitate the categorization of visual objects as a function of their ambiguity. Scalp electroencephalogram (EEG) was recorded in N = 26 participants while naturalistic object stimuli were displayed in rapid 12-Hz streams (i.e., 12 images / second, leading to a 12-Hz general response in the EEG frequency spectrum). Variable exemplars of a target category (human faces, cars, or facelike objects in different sequences) were interspersed every 9 stimuli to tag category-selective EEG responses at 12/9 = 1.33 Hz. During visual stimulation, odor contexts (body, gasoline or baseline odors) were implicitly diffused. Category-selective responses to every category are clearly isolated over the occipito-temporal cortex, with the largest response for human faces and the lowest for facelike objects. Importantly, body odors enhance the right-hemispheric response to the ambiguous category, i.e., facelike objects, which are either perceived as nonface objects or faces. This odor effect is especially found in participants who noticed the illusory faces during visual stimulation. In contrast, odor contexts do not modulate other category-selective responses, nor the 12-Hz general response, revealing a selective facilitation of the visual categorization of congruent ambiguous stimuli. Altogether, these observations indicate that the visual system can rely on non-visual cues for efficient categorization, and that olfaction, which is often considered as poor in humans, is ideally suited to assist visual categorization.

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Poster Session G > Object Recognition: Neural mechanisms > Poster G54

Generate visual metamers using fMRI and deep learning to assess the specificity of human visual processing and encoding

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This research proposes a methodological approach allowing to study the representation and encoding of the different levels of visual processing by generating metameric visual stimuli – i.e., stimuli recruiting different populations of neurons at certain levels of processing but not others. To that end, we used fMRI datasets from natural pictures and developed an encoding model predicting fMRI activation for an image, based on the activation for the same image in a robust Resnet-50 pre-trained on millions of images. Using the encoding model, we then predicted the fMRI activations associated with an image X and find the image X' (representing a metamer of X) using an Adam optimizer. The loss function minimized the distance between X and X' in some parts of the visual cortex (IT to V2) but maximized the distance in other parts of visual processing (V1). So, for the image X, we changed the loss function and calculated the images X', X'' and X''' which represent gradual metamers of image X for each part of the visual system, where X' is different from X in V1, X'' 'is different from X in V1 and V2, X''' in V1, V2 and V4. This approach allows a better understanding of the role of each level of perceptual processing by constructing a mapping of activated brain areas in a more interpretable space - that of stimuli - and make possible the development of more precise experimental protocols in visual neuroscience.

Color, Light and Material: Surfaces and materials

Poster Session G > Color, Light and Material: Surfaces and materials > Poster G55

The mental representation of materials distilled from >1.5 million similarity judgements

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Our ability to visually discriminate, categorize, recognize and compare materials is crucial for many tasks. Given the enormous variety of materials and variability in their appearance, what visual information do we rely on for distinguishing and comparing them? Here, we sought to uncover the major dimensions in our mental representation of materials, using a large-scale data-driven approach. First, we identified 200 diverse material classes sampled systematically from nouns in the American English language and collected three high-quality photographs for each class. Next, we used crowdsourcing to collect >1.5 million judgments asking which of two materials randomly chosen from the set was more similar to a third reference material, where the unchosen material acted as a context to highlight the relevant dimensions shared by the other two. We described each material image as a sparse, non-negative vector in a multidimensional representational space, modeled the assumed cognitive process for predicting choices, and iteratively used the difference between predicted choice probability and actual choice to adapt the dimensions' weights. The resulting model predicted material similarity judgments in an independent test set with >90% accuracy relative to the human noise ceiling and allowed us to accurately construct the similarity matrix of all 600 images. Similar to recent findings in the visual perception of objects, individual material images can be described as a combination of a small number of 36 material dimensions. These dimensions are highly reproducible and interpretable, comprising material categories, color and texture attributes, and more complex (e.g., mechanical) properties. Our computational model and resulting dimensions have broad application for studying material perception and its natural dimensions, such as predicting context-specific similarities, providing perceptual scales along which to rate new materials, testing the validity of ratings of material properties commonly used in the visual perception literature, and comparing behavioral representations to cortical representations.

Acknowledgements: This work was funded by the Max Planck Society, the Deutsche Forschungsgemeinschaft (DFG, German

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Poster Session G > Color, Light and Material: Surfaces and materials > Poster G56

Material recognition and the role of assumed viewing distance

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Surface material constancy under variations in object shape, illumination, and viewpoint is a remarkable achievement of the human visual system. Here, we investigated how the assumed viewing distance to a surface influences material recognition. A set of photographs depicting surfaces with ambiguous material identity were shown to observers, who provided estimates of apparent viewing distance and judgements of surface material for each image. In subsequent experiments, separate groups of observers were given contextual information about the spatial scale of the photographed scenes, either with explicit instructions (e.g., "the camera is very far from the surface") or with objects of familiar size that were digitally inserted into the images. Our experiments demonstrate that for a subset of these images, the extent of between-group disagreement about the material identity of a surface is greater when observers have conflicting assumptions about the spatial scale of the scene. These findings also indicate that materials can have canonical spatial scales; that is, the plausibility of recognizing a given material category is constrained by its characteristic appearance across changes in viewing distance. Significantly, heuristics that exploit the interdependence of material appearance and viewing distance point to a previously unacknowledged generative constraint on the statistics of images that are diagnostic of material classes.

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Poster Session G > Color, Light and Material: Surfaces and materials > Poster G57

The relationship between specular reflection image features, perceived gloss, and material category

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An often overlooked but integral aspect of object recognition is material perception, e.g., whether an object is made of plastic, pearl, satin, or steel. There is a growing body of work investigating the visual perception of the properties of materials, with a particular focus on gloss. For example, the appearance of specular reflections (e.g., their size, sharpness, and contrast) has been shown to affect how glossy a surface looks. Yet little is known about how we recognise different material classes, nor the precise relationship between material properties like gloss and material class. To investigate this, we rendered complex glossy objects in natural illumination fields. Stimuli varied in shape, illumination conditions, diffuse shading, and specular reflectance parameters. Separate sets of participants judged the glossiness and material category of each object. We found that manipulating an object's surface reflectance properties not only changed perceived gloss (i.e., how glossy is it?), but it also led to qualitative changes in perceived material class (i.e., what material is it?). We measured and then causally manipulated visual image features integral to gloss perception and found that these features also predicted changes in material appearance. Surprisingly, while linear combinations of the image features predicted perceived gloss, the strength of this linear relationship differed within each material category. This suggests that material class mediates the processing of image features for perceived gloss. Our results therefore do not support a traditional feedforward view that assumes that material perception proceeds from low-level image measurements to mid-level estimates of surface properties to high-level material classes. Instead, we suggest that the perception and neural processing of material properties like surface gloss should be considered in the context of material recognition, and more generally that the image structure that triggers our perception of surface gloss

also plays an important role in visual categorisation.

Acknowledgements: This work was supported by a Sofja Kovalevskaja Award endowed by the German Federal Ministry of Education

Poster Session G > Color, Light and Material: Surfaces and materials > Poster G58

Learning From Paintings Improves Representations for Fabric Recognition

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Material classification is the task of distinguishing materials like fabric, wood, ceramic, and so forth. Fine-grained classification aims to distinguish subcategories of a material (e.g., satin fabric versus wool fabric). Fine-grained recognition relies on identifying specific visual attributes (e.g., satin is glossy while wool is not) over contextual cues (e.g., both satin and wool are used as clothing). In paintings, artists carefully place visual cues like highlights on fabrics like silk or satin; as such, we hypothesize that learning a visual recognition model from paintings can be beneficial. In this study, we explored the representations learned by neural networks for the task of distinguishing silk/satin from cotton/wool. We trained separate models on paintings from the Materials In Paintings (MIP) dataset and on photos from Flickr, and extracted evidence heatmaps that indicate which cues are used by the models in unseen test images. We conducted a study with 57 quality-controlled participants on MTurk to analyze which model uses cues that are preferred by humans. Overall, we found the model trained on paintings utilizes cues that are better preferred by humans. Furthermore, we found that both models use cues that are equally preferred when tested on photos of silk/satin. This is interesting as the model trained on paintings has never been explicitly trained to classify photos of satin/silk, and conventional wisdom dictates that the painting model should fail to extract cues that are comparable to the cues used by the photo model in this setting. Furthermore, the painting model generalizes better across domains with respect to prediction accuracy. While this study is limited to two fine-grained classes of fabric, our results show that perceptual depictions in paintings can be useful for guiding deep neural networks.

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Poster Session G > Color, Light and Material: Surfaces and materials > Poster G59

Perceptual scale for transparency

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The colors of transparent objects, such as gemstones, have a unique quality closer to light than surfaces, which is both beautiful and an enigma. While viewing a transparent object, our eyes receive light that is a multiplicative composite of surface, illumination, and filter spectra. Yet, when we observe the color of a transparent object, we simultaneously perceive surface and overlay layers in two different colors at the one retinal locations. How our brains separate the information and extract the transparency color remains a mystery. Physical characteristics of transmitting layers could provide cues for transparency separation by generating images with stereotypical geometrical and color features, such as X-junctions, multiplicative contrast changes, 3-D diagonal color transforms in cone space, and revealing motion. We compared the importance of such cues, by estimating a perceptual scale for transparency with stimuli where X or T junctions, revealing or occluding motions, and consistent or inconsistent colors, combine or compete in forced-preference psychophysics experiments. We found that motion works as a facilitator by separating layers for geometric cues to assign as transparent or opaque, and that geometric cues can override color inconsistency. A probabilistic graphical model provides a quantitative estimate of the influence of different factors on perceived transparency.

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Individual Differences in Classification of Translucent Materials Using Photos of

Real-world Objects

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Many real-world materials are translucent (e.g. skin), but our understanding of translucency is very limited. Previous findings of human perception of translucency are mainly based on rendered images, which are restricted by their diversity of appearance and realism. We measure observers' translucency perception with photographs of real objects. Here, we examine individual differences and the role of color in perceiving translucent appearance through a classification task. Observers had unlimited time to classify 250 images as “Translucent”, “Opaque” or “Unsure”. Stimuli are photographs of real objects made of natural or artificial materials, such as fruits, wax, ceramics. In Experiment 1, the stimuli are presented as RGB images. In Experiment 2, the images were converted to grayscale by extracting the luminance channel. Twenty-five observers completed each experiment. First, we found substantial individual differences in both color and grayscale conditions. In the color condition, only 22% images reached 96% agreement among observers wherein grayscale condition 24% images reached 96% agreement. Furthermore, more observers reported “Unsure” in the grayscale condition in comparison to the color one. We constructed the representational dissimilarity matrices (RDMs) based on individual votes for each image pair for both conditions. The patterns of the image-by-image RDMs are visually different between the color and grayscale conditions (Kendall's $\tau A=0.27$, $p<0.01$), revealing a shift in observers' responses to certain stimuli and a significant but weak correlation between the two RDMs. For example, some objects (e.g. tennis ball) uniformly voted as “Opaque” in the color conditions were voted by some observers as “Translucent” in the grayscale conditions, thus, resulting in more individual difference. Our results suggest that there are substantial individual differences in translucency classification from photographs of real objects, likely due to interpersonal differences in interpretation of translucency and object categories. Moreover, removing color has an effect on the votes for some stimuli.

Acknowledgements: American University CAS Faculty Mellon Fund.

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A striking take on mass inferences from collisions

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Our everyday activities – e.g., packing groceries, building sandcastles – require knowledge about the physical properties of the objects and surfaces in our environments. We often learn about properties such as weight, hardness, and slipperiness by interacting with the world, but we also learn about latent physical properties by observing events. Among the best-studied examples is people's ability to infer objects' relative masses based on seeing them collide, and work on this front has shown that people's inferences sometimes show marked biases. For example, when an incoming object strikes a stationary one, people consistently overestimate the mass of the incoming object. Why? Various accounts attribute the effect to heuristics that fail in certain conditions, simplified stimuli that lack realistic cues, or a characteristic of rational Newtonian decisions made under sensory uncertainty. Here we sought to disentangle these competing accounts by asking observers to judge the relative weights of bowling balls in videos of real collisions. Balls ranged from 6 to 16 pounds; subjects saw all possible pairings and reported whether the incoming ball or the initially static one was heavier. Under these realistic conditions, participants still consistently overestimated the incoming ball's weight. We found reliable individual differences in the size of this bias, and in overall performance in weight discrimination. While weight discrimination performance was predictive of intuitive physics abilities in general (assessed with an independent task battery), bias in weight estimation showed no relationship, suggesting it is not a hindrance in other tasks. In a final experiment, we occluded cues in the videos that the purported heuristics would rely on, and we found it had little impact on overall weight discrimination or bias. Our results argue against accounts based on heuristics or oversimplified stimuli and support the idea that the bias is a characteristic of a well-tuned Newtonian system.

Poster Session G > Color, Light and Material: Surfaces and materials > Poster G62

Perceptual haptic representation of materials emerges from efficient encoding

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It was proposed that perceptual representations emerge from learning to efficiently encode sensorial input. For instance, the highly correlated excitations of the long- and middle-wavelength-sensitive cones in the retina are transformed into an efficient decorrelated representation (i.e. two color-opponent and a luminance channel). There is currently a lot of interest whether higher level representations can also be learned by efficient encoding of the sensorial input in vision and other senses. Here we test the hypothesis that haptic perceptual representation of materials emerges from efficient encoding. When touching the surface of a material, its spatial structure translates into a vibration on the skin. The perceptual system evolved to translate this pattern into a representation that allows to distinguish between different materials. We trained a deep neural network with unsupervised learning (Autoencoder) to reconstruct vibratory patterns elicited by human haptic exploration of 108 samples of different materials. The learned compressed representation (i.e. latent space) allows for classification of material categories (i.e. plastic, stone, wood, fabric, leather/wool, paper, and metal). More importantly, distances between these categories in the latent space resemble perceptual distances (computed from human judgments of material properties, e.g. roughness, after visual or haptic exploration), suggesting a similar coding. These results support the idea that perceptual representations emerge from unsupervised learning as a consequence of efficient encoding of the sensory input. We could further show that the temporal tuning of the emergent latent dimensions of the Autoencoder is similar to properties of human tactile receptors (Pacinian and Rapidly Adapting afferents), suggesting that our tactile sensors evolved to efficiently encode the statistics of natural textures as they are sensed through vibrations. We could replicate our findings with four different networks, suggesting that our results do not depend on the choice of the network's architecture.

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Color, Light and Material: Color 2

Poster Session G > Color, Light and Material: Color 2 > Poster G63

Color-selective brain responses and hue representations from ultra-high-field fMRI of natural scenes

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Color selectivity in early visual cortical regions has been relatively well studied using fMRI, but less is known about responsiveness to chromatic stimuli in cortical regions beyond V4. One study by Lafer-Sousa et al. (J. Neurosci., 2016) found three color-biased regions (posterior, central and anterior) along the ventral visual pathway located between face- and place-selective cortical areas. We have investigated color selectivity in visual cortical areas using the Natural Scenes Dataset (NSD; Allen et al., J. Vision, 2020), a large-scale fMRI dataset of BOLD responses in 8 participants who each viewed 9,000-10,000 color natural scenes (22,500-30,000 trials). In a whole-brain analysis we correlated the average color saturation of the images (relative to background grey) with the responses of each voxel. Our results confirm the existence of posterior, central and anterior color-biased regions in the ventral stream. Furthermore, given the high signal-to-noise ratio provided by NSD, we observe color-selective regions extending further anteriorly than those identified by Lafer-Sousa et al. Importantly, our results reveal that color selectivity diverges into two distinct streams in the ventral visual pathway. We created regions of interest (ROIs) within these two streams and have identified the images within each ROI that elicit the largest responses, allowing us to characterize the properties of color selectivity in the two streams. We also characterized hue-specific representations in visual cortical areas. For 8 hue bins, we conducted a representational similarity analysis, first grouping images based on the relative proportion of pixels in each hue bin and selecting the highest 500 images per hue bin. We then constructed representational dissimilarity matrices from the average activity across images in each hue bin and used multidimensional scaling to reconstruct 'neural' color

spaces. Our results show distinct and reliable patterns of hue representation for different visual cortical areas.

Acknowledgements: Collection and pre-processing of MRI data was supported by NSF IIS-1822683 (K.K.), NSF IIS-1822929 (T.N.), NIH S10 RR026783, the W.M. Keck Foundation, the analyses described here by European Research Council grants COLOURMIND 772193 (AF) and COLOURCODE 949242 (JB)

Poster Session G > Color, Light and Material: Color 2 > Poster G64

How to make a #TheShoe

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That color appearance is subject to scene interpretation is shown by images, in which object color distributions may be confused with lighting along the daylight locus. In previous work, we have shown that such images yield striking individual differences in color perception, like those observed with the famous #TheDress. Yet, #TheShoe raises questions about the role of the daylight locus because it seems to produce individual differences even though its color distribution is (approximately) orthogonal to the daylight locus. We wanted to know whether confusions between object and lighting colors occur beyond the daylight locus and yield striking individual differences comparable to those observed with #TheDress. For this, we adapted our algorithm for dress-like images to produce new images with the colors of #TheShoe. We conducted two online studies and a lab study. In these studies, we presented a range of dress-like and shoe-like images and asked observes to describe their colors with color names and to match them through color adjustments. Results strongly confirmed our previous observations of individual differences for a large range of dress-like images, including a #TheShoe version with dress-like colors. Most importantly, we consistently observed across both surveys, systematic individual differences for images with shoe-like colors, including a #TheDress with those colors. These individual differences for images with shoe-like colors were correlated one with another, and with the individual differences observed for #TheDress. These correlations imply that individual differences are systematic across different images. Together, these findings suggest that confusions between object and lighting colors are not bound to the daylight locus but may occur for a large range of images with object color distributions aligned with one hue direction.

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Poster Session G > Color, Light and Material: Color 2 > Poster G65

How fast does the color of daylight change?

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Natural illumination undergoes changes in hue and saturation associated with sun elevation, yet people do not seem to perceive these changes directly. Previously, we measured speed detection thresholds of smooth changes in daylight metamers and showed that discrimination of chromaticity changes depends on the Correlated Color Temperature (CCT) of the base (adapting) illumination: cool-changes become less noticeable for progressively warmer base lights and vice-versa (Pastilha et al., 2020). Here we analyze temporal variations of real daylight. We aim to determine the velocity range of daylight chromaticity changes and compare it to the previously found discrimination thresholds (Pastilha et al., 2020). We use databases of spectral irradiance measurements of outdoor downwelling light taken at regular intervals from dawn to dusk, at different locations in the northern hemisphere. Daily spectral data were collated by month. Estimates of the maximum velocity of daylight chromaticity changes for each month were obtained from smooth fits to the aggregated data, taking into account all possible CIELUV white points from the daylight locus. In all months and locations, the fastest CCT changes occur at sunset and sunrise, but speeds depend on day length and vary throughout the year. For a 2-year dataset from Granada, Spain (Hernández-Andrés et al., 2007), the largest velocity estimate is about 0.02 $\Delta Eu^*v^*/s$, occurring in January. Similar estimates (0.03 $\Delta Eu^*v^*/s$) are found for a 20-day dataset from Stanford, USA at the same latitude (37º) and month (DiCarlo & Wandell 2000). Note that here, concomitant changes in lux - which may be significant - are not considered. The maximum velocity of chromaticity change in daylight is much

slower than the minimum illumination velocity discriminated by the observers in our previous experiments (0.5 ΔEu*v*/s), at least for these daylight measurements. These results suggest that outdoor CCT changes are too slow to be detected.

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Poster Session G > Color, Light and Material: Color 2 > Poster G66

Variations of saturation in natural objects and their effects on perception

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Despite its perceptual significance, saturation is the least studied and least understood attribute of color. In CIELAB color space, it is calculated at the pixel level as a function of intensity (L*) and chroma (C*): C*/L*. However, within natural objects, chroma co-varies systematically with intensity in two different ways, depending on the nature of the interaction between light and surface. The body reflection is derived from the pigment composition of the object and varies mainly with shading; in the CIELAB L*-C* plane, the correlation between intensity and chroma is positive for this component: the brightest pixels are high in chroma and the darkest are low in chroma. The surface reflection results from the interface between the illuminant and the object's outermost surface edges. It leads to a negative correlation between intensity and chroma: the brightest pixels have a low chroma, in line with the chromaticity of the illuminant. Here, we systematically varied the correlation between chroma and intensity to see whether this has effects on the perception of saturation. We used hyperspectral images of various fruit objects, as well as matte objects rendered using Mitsuba Renderer. For these objects, nearly all of the color variation was captured by the first principal component of all pixel values in CIELAB color space. We then manipulated the slope of this line, keeping basic chromatic statistics such as mean, variance, and range constant. Objects with a negative correlation between intensity and chroma were perceived to be much less saturated than those with a positive correlation. These results suggest that the perception of saturation cannot be explained by elementary statistics such as mean pixel saturation. Rather, the visual system estimates the underlying causes—illumination or pigmentation—and uses this implicit knowledge about the physics of light and surfaces to make judgments about invariant object properties.

Poster Session G > Color, Light and Material: Color 2 > Poster G67

Saturation as a function of stimulus size: dependence on thresholds and luminance contrast

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Knau and Werner (2002, JOSA A, 19, 208-214) demonstrated that saturation of parafoveally presented colours changes as a function of stimulus size - smaller single wavelength stimuli were found to appear increasingly desaturated, with a stronger effect for older compared to younger observers. Our study successfully replicated their findings using isoluminant colours that isolated the two cone-opponent mechanisms: reddish, greenish, bluish and yellowish. Perceived contrast of a circular patch, varying in size (2˚, 1˚, 0.5˚, 0.33˚, 0.20˚, 0.15˚), presented at 4˚ or 5˚ eccentricity was matched to a 2˚ standard patch at 5.5˚ eccentricity by a group of younger (22-39 years) and older (60-82) observers. Desaturation occurred from 0.33˚ onwards in the younger group and 0.5˚ onwards for the older observers, who showed a more pronounced effect overall. Desaturation was present for all colours and was strongest for bluish stimuli. To better understand these findings, contrast detection thresholds were measured for a group of younger observers using a subset of stimulus sizes. Whilst a clear increase in detection thresholds with a decrease in patch size was observed, there were no asymmetries between mechanisms, contrary to the matching experiment. The desaturation thus cannot be fully explained as a linear consequence of changes to detection thresholds. Finally, the same matching paradigm was used with a group of younger observers on a subset of stimulus sizes, examining if desaturation also occurs if colours contain a suprathreshold luminance signal. This time, desaturation with a reduction in size only occurred for blue. While desaturation of small isoluminant stimuli may be the product of optical factors, desaturation for blue even in the presence of luminance contrast points towards a cortical contribution, in line with exiting literature. Our results imply that colour

appearance models based on 2 stimuli cannot fully capture saturation if stimuli are small (≤0.5).

Poster Session G > Color, Light and Material: Color 2 > Poster G68

Is color discrimination influenced by the chromatic statistics of different visual environments?

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The distribution of chromaticities in natural scenes is elongated along the blue-yellow axis. Color discrimination thresholds are also poorest along the blue-yellow axis, which may reflect calibration of color vision to the visual environment (Bosten, Beer & MacLeod, 2015). The hypothesis of whether or not color vision can be calibrated within an individual's lifetime to the content of the scenes they encounter can be tested by comparing individuals who live in chromatically different environments. We compared color discrimination in individuals living in different visual environments (in two cities (Brighton (UK), Quito (Ecuador)) and a rainforest community in Esmeraldas (Ecuador)). Here we developed a psychophysical method of efficiently measuring color discrimination ellipses on a calibrated tablet. Color discrimination thresholds for 8 hues were measured for participants at the three locations. Additionally participants wore calibrated head mounted cameras to capture a representative sample of the natural scenes that they encounter in daily life. All of the images were analysed for their color distributions to characterise the differences in color statistics between the three environments. Discrimination thresholds for all three groups were poorest for the blue-yellow axis (Brighton, $t(34)$, 12.47, p=<.001,Quito, $t(20)$= 6.129 p=<.001, Esmeraldas, $t(25)$ = 8.23, p=<.001). The distributions of colors in natural scenes were also biased along the blue-yellow axis in all three locations. However, despite differences in the chromatic distributions of scenes at different locations, these differences could not easily account for color discrimination performance.

Acknowledgements: Research supported by European Research Council grant COLOURMIND (772193) to AF.

Poster Session G > Color, Light and Material: Color 2 > Poster G69

Color ensemble percepts from three-dimensional color variation.

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Ensemble color percepts are biased towards higher chroma (e.g., Kimura, 2018), but it is unknown whether this bias also affects perceived hue when chroma and hue are correlated. We studied whether hue is processed independently of chroma and lightness by varying their respective correlations in color mosaic stimuli and measuring perceptual biases. Stimulus colors were defined in LCh-coordinates of the CIELUV color space. Preliminary experiments determined observers' just noticeable differences (JND) for lightness, chroma and hue. The test stimulus was a 6-by-6 grid of 0.5-degree square elements of uniform color, displayed against a gray background with chromatic noise. In different experimental conditions, the hue, lightness and chroma values of the stimulus elements were either fixed or variable in proportion to the observer's JNDs. Variation in one dimension could be independent of, or perfectly correlated with, one of the other dimensions. The comparison stimulus was the same size as the test, but without color variation. In Experiment 1, the test and comparison stimuli were presented sequentially for 500ms. Depending on the condition, the observer compared them in terms of hue, chroma, or lightness. The comparison stimulus value was varied over trials, and the perceived color of the test was estimated by fitting psychometric functions to the proportion of bluer/more chromatic/lighter responses. In Experiment 2, observers adjusted the comparison stimulus to match the color of the test in all three dimensions simultaneously. Observers showed a bias towards higher chroma, but not towards the correlated hue. In contrast, there was no bias in lightness estimates, but a bias towards the hue correlated with higher lightness. The different dimensions of color do not seem to be averaged jointly, and chroma and lightness variations have distinct effects on the color ensemble percept. References: Kimura, E. (2018). Averaging colors of multicolor mosaics. JOSA A, 35(4), B43-B54.

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Making a Display look like Paper: the Effects of Adaptation Duration and Luminance

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Making emissive displays look like reflective surfaces is one goal of “calm display” technology. It may be achieved by adjusting the colour appearance of the display to match that of paper, following changes in illumination and viewing conditions. A previous cross-media colour matching study (Kučera et al. VSS2019) found discrimination ellipses of 16×6 ΔEab size on average, with scatter in chroma up to 3.67× larger than in hue. The study suggested that given freedom to adjust luminance, observers selected higher chroma at higher luminance and vice versa. Matching duration was also unconstrained. Here we ask how fixed luminance and adaptation duration affect cross-media colour matching. Participants (n=49) viewed an IPS LCD display next to a white card (RAL 000 90 00), each sized 10°, in an enclosed achromatic booth illuminated by tuneable multi-channel LED lamps. Light from the lamps was prevented from reaching the display. Following an initial 2-min adaptation under D65 illumination, participants had 5 minutes under the test illumination to adjust the display’s chromaticity to match the white card. Every 30 seconds, the adjustment joystick was disabled for 30 seconds while observers adapted to the test illumination. The display luminance was fixed to match the white card. Six test illuminations with equal illuminance levels (D65 and saturated red, green, blue, cyan and yellow) were presented three times each in randomized order. Results: PCA analysis of matches shows that with fixed luminance, discrimination ellipses are 3.4× smaller than for matches with adjustable luminance, and the “super-importance of hue” effect weakens considerably, but least for blue illumination. Overall, the scatter remains larger than for same-media matches (cf Luo and Rigg) across all individuals and timepoints – discrimination ellipses span 8.56 × 3.94 ΔEab on average. Increasing exposure time improves accuracy and consistency of matches, but not for everyone.

Color, Light and Material: Cognition and preference 2

Poster Session G > Color, Light and Material: Cognition and preference 2 > Poster G71

Effects of inter-reflections in box spaces on perceived object color harmony and shape

View Poster | Visit me in Gather.Town Manatee Room on Tuesday 8:00 am - 10:00 am EDT

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The effective illumination incident on an object in a three-dimensional scene is a geometrically-weighted sum of direct and indirect light. The luminous and chromatic properties of the light field vary spatially and directionally, inducing luminance and chromatic gradients - smooth color variations over objects. When a color combination of a step or gradient produces a pleasing effect, it is said to be harmonious. Previous studies have shown that perception of color harmony is dependent on a complex interplay between hue, chroma and lightness (Ou and Luo, 2006). Further, the visual cues from luminance and chromatic gradients might assist three-dimensional shape recovery (Ruppertsberg et al., 2008). The aim of this research is to investigate the influence of chromatic furnishing materials on the perception of object color harmony and shape, through inter-reflections. Box spaces were rendered with uni-chromatic surfaces and a colored sphere, acting as a probe, in its center, illuminated by a planar white illuminant. 24 room surface colors were sampled systematically in RGB space. The sphere’s color was sampled from the 15 CIE CRI color checker samples. Participants had to rate perceived three-dimensionality (flat disk vs. sphere) and color harmony (disharmonious vs. harmonious) of the rendered sphere under carefully calibrated conditions. Before each session and between trials, participants adapted to an animated noisy mask. A short training session introduced randomly selected stimuli after which the main experiment took place. Of the tested furnishing hues, the bluish rooms resulted in the highest mean color

harmony and three-dimensionality scores. Decreasing the furnishing brightness resulted in a major three-dimensionality enhancement, as expected. Reducing the saturation and even more so the brightness of the chromatic furnishing colors enhanced the perceived color harmony of the probe. These effects show the importance of 3D versions of color checkers, here we used spheres, for color testing.

Acknowledgements: This work was supported by the Marie Skłodowska-Curie Action – Innovative Training Network (MSCA-ITN-ETN) DyViTo: "Dynamics in Vision and Touch – the look and feel of stuff" under the European Union's Horizon 2020 research and innovation program [grant number 765121, 2017]

Poster Session G > Color, Light and Material: Cognition and preference 2 > Poster G72

Mapping a low-dimensional space of color-concept associations

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People systematically associate colors and concepts, a phenomenon that can either help or hinder the interpretation of color in information visualizations. For instance, by applying optimization algorithms on color-concept association ratings, one can create palettes that are easily interpretable without legends (Schloss et al, 2018). Yet such optimization requires the designer to quantify associations between each concept and a large range of colors, to avoid the conflicts that arise when multiple concepts evoke the same strongest associates. Collecting association ratings for all possible colors and concepts is prohibitively costly and time-consuming. We therefore considered whether the space of color-concept associations can be expressed using low-dimensional representations. If so, that would mitigate the need for exhaustive human ratings and enable extrapolation of a limited set of ratings to new concepts and colors. To test this possibility, we collected color-concept association ratings for 30 concepts (spanning diverse concrete and abstract conceptual domains) and 58 colors (sampled uniformly over CIELAB space). Using principal components analysis (PCA) on the mean color-concept association ratings, we determined 8 'color profiles' that strongly captured the structure of color-concept associations (90% variance explained). From these profiles, we fit regression models to estimate association ratings between new, unobserved concepts and colors. These models predicted both how sensitive each profile was to hue, lightness, and chroma and what blend of the 8 profiles best captured the color associations for a given concept. Using a leave-one-out approach and querying a subset of colors, we strongly predicted ratings for held-out concepts (mean correlation of 0.82 between true and predicted ratings). Our method can be used to automatically generate easily-interpretable color palettes for visual communication. Moreover, our results indicate that the mental representations underlying color-concept associations are highly structured, opening the way for a more principled understanding of color semantics.

Poster Session G > Color, Light and Material: Cognition and preference 2 > Poster G73

The Colour of Nostalgia

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Associations between colours and emotions have been evoked in many contexts, including literature, cinematography, and marketing. There is evidence that colours are associated with emotions such as happiness, sadness, and anger. It remains an open question whether those associations are based on cultural conventions or reflect a meaningful link between perceptual and emotional experiences. Nostalgia is an interesting test case for the emotional significance of colours, because this emotion is complex and bittersweet (simultaneously happy and sad). It also evokes memories of the past that may be the source of colour associations. We conducted two online surveys (N=191; N=489) with a different set of colour stimuli each (calibrated assuming sRGB). For each colour, participants indicated its association with nostalgia using a slider. They also rated how happy, sad, positive, and negative they felt about nostalgia, and entered three concepts they associated with nostalgia. Results from both stimulus sets indicate that slightly desaturated colours are most strongly associated with nostalgia. Participants associated nostalgia with specific concepts (childhood, photos, friends), but these concepts were uncorrelated with colour ratings. We also compared nostalgia-colour associations with colour preferences and colour-emotion associations from previous studies. We observed a negative

relation between colour preferences and nostalgia-associations, due to greenish-brown colours being strongly associated with nostalgia, but least preferred (r[485]=-0.38, p=0.03). Colour preferences and associations between colour and happiness were also related to individual differences in colour-nostalgia associations: observers who rated nostalgia as more positive and happier associated nostalgia with colours that they preferred less (r[485]=-0.24, p<0.001) and rated as happier (r[485]=0.27, p<0.001). These results imply that colours express the affective valence of nostalgia. However, a comparison across the two surveys suggested that cultural differences and colour samples may be relevant. Research will need to address these issues before drawing definitive conclusions about the colour of nostalgia.

Visual Search: Spatial, temporal, memory

Poster Session G > Visual Search: Spatial, temporal, memory > Poster G81

The Role of Target Representation in subsequent search misses effect

View Poster | Visit me in Gather.Town Dolphin Room on Tuesday 8:00 am - 10:00 am EDT

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Subsequent search misses (SSM) effect is the decrease in accuracy of second target detection after finding the first target in visual search task. According to resource depletion and “perceptual bias” accounts functioning of attention underlies the SSM errors (Cain et al., 2013). The purpose of the current study was to experimentally estimate the role of attentional template in SSM errors. Participants completed a visual search task with real-life objects. The targets were indicated at the beginning of each trial. Three types of templates were used: the verbal title of the target category, the morphed averaged image of an object from a category, or both title and image. Participants’ task was to find all the targets or to report their absence. On each trial, there could be one, two or no targets. In dual-target trials, targets could be identical images or different images. Target report accuracy was analyzed for different target templates and target similarity conditions. Two-way rmANOVA revealed the effects of target template ($F(2, 57) = 6.074$, $p = 0.004$; $\eta p2 = 0.167$) and targets identity ($F(1.780, 101.444) = 11.402$, $p < 0.001$; $\eta p2 = 0.176$). The significant SSM effect was revealed for identical, but not for different targets when the targets were defined as the verbal title of the target category ($W = 160.500$, $p = .040$). SSM effect was also found for different targets when the target was defined as a morphed averaged image of an object from a category ($t = 3.283$, $df = 19$, $p = .004$). For both image and title template condition, SSM effects were also found for different targets ($t = 3.476$, $df = 19$, $p = .003$). Overall, detailing of the target template had the impact on SSM errors. However, the effect depends on stimuli identity.

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Poster Session G > Visual Search: Spatial, temporal, memory > Poster G82

Serial dependence from distractor stimuli at irrelevant locations

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Serial dependence (SD) is a bias in reporting stimulus features as more similar to the recently presented stimuli than they actually are. Several studies suggest that SD increases when similar features are attended at nearby locations, suggesting that selective and spatial attention plays a role in SD biases. Selective attention typically involves both the selection of targets and the suppression of distracting information. For instance, spatial locations frequently associated with a distractor can be implicitly suppressed. Here we investigated whether stimuli occurring at spatially suppressed locations cause SD. Participants performed a sequential dual-task, with visual search trials followed by an orientation adjustment task. In the visual search task, observers determined the location of the open side of a Landolt C presented in one of four locations. On half of the trials, a distractor (an oriented Gabor) was presented in one of the remaining locations. The distractor location was kept constant or randomly varied in two separate conditions. In the orientation adjustment task, a test Gabor was presented at one of the locations, including the distractor location on distractor present trials. The adjustment task involved reproducing the Gabor orientation by rotating a response bar. We found significant attentional capture in the search task (slower reaction times) due to the distractor, independently of whether its location was constant or variable. SD was quantified as the deviation of adjustment responses toward or away from previous stimuli. When SD was measured for the test Gabor in the preceding trial, we replicated the classical attractive bias. SD for the distractor Gabor, however, showed a repulsive bias. Our results demonstrate the differential SD effects of the attended and ignored features. However, the lack of a spatial suppression indicated by search times presents a puzzle for the mechanism behind the SD bias induced by the distracting information.

Previous fixations do not facilitate search when a distractor becomes a target

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Our day-to-day experience suggests that, with repeated exposure, we can easily acquire information about our environment. However, it is not clear how much exposure is needed for information to be useful for task performance. In a previous study we found that searching for different targets in the same set of 72 items did not facilitate search for other items within the same set. In this study we analyzed whether this was still the case when all targets shared one feature (color). In each trial a target letter was presented at fixation, followed by the search display. The search display was made of 72 colored letters (12 letters x 6 colors) and was the same for all searches (repeated visual search). Twelve different orange letters were used as targets. Location was constant for each target, but targets differed in eccentricity. Each target was searched for 6 times. We compared the results of two groups of participants. For the first group all 12 letters were targets in each block of trials. For the second group one of the letters, 'W', became a target only in the last two blocks of trials. Our goal was to determine if previous fixations on this letter while searching for other letters facilitated search. Results showed that RT decreased significantly with target repetition for all letters. Critically, when we compared RTs for the first search of the letter 'W' we found that RTs were similar. This was the case even though the second group of participants had performed 55 trials before searching for the W and had made, on average, 8 fixations on that letter during those trials. This suggests that just fixating an element when it is not a target is not enough to produce a memory trace. Facilitation requires repeatedly searching for the same item.

Target Detection Vulnerability to Low Target Prevalence Across Display Type and Speed

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Visual search is an integral element of various professions, such as airport security screening, radiology, security surveillance, and military sonar operation, in which a single miss could have disastrous consequences. Conditions of visual search vary across different real-world tasks; for example, targets of varying prevalence and display rates can appear in dynamic or static environments. Despite research on how each condition influences task performance (Peltier & Becker, 2016; Wang & Sun, 2015), the extent to which they interact is unclear. It is therefore vital to investigate which search conditions/interactions affect target detection and how. This study randomly assigned 563 participants across eight conditions of a visual search task. Participants had to detect known targets, "T"s, within a display of distractors, offset "L"s (Peltier & Becker, 2016). Conditions varied between a dynamic (continuous horizontal scrolling) or static display type, a high (50%) or low (10%) target prevalence rate, and a fast (3.5 seconds) or slow (7 seconds) display speed. The current study did not detect a significant impact of search conditions on false alarm rates. Doubling the allowed search time produced a 55% increase in target detections, likely attributable to participants having increased time to process and inspect display items. Lower target prevalence resulted in decreased hit rates, consistent with the low prevalence effect (LPE). Notably, display type did not have a significant effect on hit rate, suggesting that both dynamic and static displays are vulnerable to the LPE. To mitigate LPE, successful methodologies applied to static

searches in the past—such as artificially-increased prevalence rates (Wolfe et al., 2007) to increase target detections—should be considered for evaluation and potential implementation into dynamic conditions, in which such methods could be used to improve real-world visual search performance.

Poster Session G > Visual Search: Spatial, temporal, memory > Poster G85

Gaze cues from the past can attenuate change blindness in the flicker paradigm

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An observer will often pay greater attention to an object that is the target of another person's gaze than to other objects in a scene, a phenomenon known as gaze cuing. What about objects that were the target of another person's gaze in the recent past? We used the flicker paradigm to address this question. In this paradigm, two versions of a scene are cyclically presented with a brief blank in between each presentation. Under such conditions, observers often fail to see the change until attention is directed to the changing region. In experiment 1, participants (N = 21) searched for changes in pictures of complex, real-world scenes. For each participant, half the scenes contained a valid a gaze cue (i.e. a person looking at and reaching for the changing object), and the other half did not (i.e. no person was present). The stimulus set was created such that each scene could be used in each condition across participants, thus controlling for low-level differences between the cued and un-cued changes. As expected, reaction times were faster when a gaze cue was present (M = 7.34 seconds) than not (M = 11.22 seconds; $t(20) = 2.55$, $p = 0.019$). In experiment 2, on each trial participants (N = 50) viewed a one-second preview the scene before the flicker sequence began. Half of the previews contained a valid gaze cue, and the other half did not. The scenes presented in the flicker sequence did not contain people at all. Reaction times were faster when the preview contained a gaze cue (M = 4.11 seconds) than when it did not (M = 11.56 seconds; $t(49) = 7.18$, $p < .001$). These results suggest that memory for gaze can be as effective as perception of gaze at directing attention in the flicker paradigm.

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Effects of working memory load in visual search in development

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Relevant theories in VS consider WM processes key to understand how humans search in visual tasks. But there are still inconsistent results when loading WM within a dual-task paradigm where an observer must concurrently perform a VS task. However, all these results are based on adults' studies. From our knowledge, there are no such studies in development where these cognitive capacities are still growing. Understanding how WM load can modulate VS in development could give us more clues about the role of WM in VS. This is the objective of the present study. We tested 119 children between 5-12 years old and 32 young adults in a dual-task in which observers had to maintain several real-world images in two high/low WM-load conditions while performing a concurrent VS task (looking for a given real-world image target among several real-world images-distractors). Results on WM show better performance as age increases. However, performance is high even for the youngest children (70% in the most difficult high-load condition, and over 80% for the rest). WM load also impairs selective attention as age decreases: Younger observers spend more time deciding whether the VS target is present/absent under high-WM loads. As age increases, this effect disappears, replicating previous studies with adults. Results on general VS measures replicate those found in other similar studies in development. For young adults, attentional control is developed enough to concurrently perform WM and VS tasks. For younger children, it is not. Although there are differences in WM performance among ages, the performance is very high even for the younger observers. Probably attentional control, rather than WM capacity per-se, could be fundamental to explain these WM-selective attention interactions in VS.

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Working memory resources protect attentional templates during visual search: Converging evidence from event-related potentials

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Attentional templates are representations of target features in Working Memory (WM) that guide visual search. While transiently active templates are as efficient as templates held in a sustained fashion, their simultaneous activation generates costs for the sustained template (Berggren, Nako, & Eimer, 2020). Based on models that conceptualize WM as a limited resource, Huynh Cong and Kerzel (2020) proposed that WM resources could serve a protective function in visual search. In a series of behavioral experiments, they demonstrated that the allocation of resources in WM could modulate the sustained template costs. Here, we investigated this question by recording electrophysiological correlates of resource allocation (CDA) and attentional selection (N2pc). Two target colors were cued before onset of the search display. In blocked trials with variable targets, both colors changed on every trial. In blocked trials with fixed targets, both colors remained identical throughout. In the mixed condition, one color was fixed while the other varied from trial to trial. Consistent with sustained template costs, RTs were delayed and N2pcs were attenuated to fixed compared to variable targets in the mixed condition. In contrast, RTs and N2pcs were similar to fixed and variable targets in the blocked conditions. Critically, we observed the exact inverse pattern on the CDA. While transient templates elicited larger CDAs than sustained templates in the blocked conditions, there was no difference between both types of attentional templates in the mixed condition. Follow-up analyses showed that the CDA elicited by the sustained template increased from the blocked to the mixed condition. Therefore, more WM resources were allocated to the sustained template when maintained concurrently with an interfering transient template. While the associated costs were still present, the increase in resources may be necessary to protect the sustained template, allowing it to conserve a precise representation in WM despite interference.

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Canonical specular and velvety material modes form a basic feature in visual search

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Wolfe and Myers (2010) tested whether materials guide our search in visual scenes. They used the stimuli from the Flickr Material Database (FMD) and found no evidence that our search is efficiently guided by materials. For example, searching a fur patch among stone patches turn out to be highly inefficient. FMD was developed to capture a range of real-world materials, in which the surface appearance per material class may vary largely. Here we present results from a standard visual search experiment using the images of canonical material modes (velvety and specular) as stimuli. Participants searched for a velvety image among specular images (distractors) vice versa. There were four set sizes, 4, 9, 16, and 25. Images of canonical materials provide key image features that trigger corresponding material perception, namely the bright contours for velvety and the highlights for specular material (e.g., Zhang et al., 2019). To ensure that participants only use these material-related perceptual features instead of sole perceptual features, the lighting direction was randomly varied throughout the experiment. In addition, the 3D-shape of the materials was either a sphere or a blob. Overall, there was a significant set size effect with a search slope of around 3ms/item in target-present trials and 4 ms/item in target-absent trials, indicating an efficient search. However, the efficiency significantly varied with the type of material. The slopes of velvety target were 4.5ms/item and 9ms/item in target-present and target-absent trials, respectively, while that of specular target was flat for both conditions. Hence, specular clearly constitutes a basic feature in the sense of Treisman's FIT. For velvety, evidence is less strong. In other words, our study presents a first evidence that material perception may extract basic features, i.e., contradicting Wolfe and Myers' (2010) study. To strengthen our

claim further studies will test more canonical materials.

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Assessment of Perceived Task Difficulty Across Multiple Search Conditions

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Various conditions of real-world visual search may impact search performance and perceived difficulty. Given the necessity of accurate target detection across professions, this study explored the conditions in which visual search performance and perceived task difficulty may be affected. Conditions varied between a dynamic (continuous horizontal scroll) or static display, a high or low (50% or 10%) target prevalence, and a fast or slow (3.5 or 7 second) display speed. Participants (n = 563), recruited through Amazon Mechanical Turk (MTurk), were randomly distributed across eight conditions of visual search and tasked with determining the presence of known targets, "T"s, amongst a display of distractors, offset "L"s (stimuli from Peltier & Becker, 2015), as well as rating their perceived work load via the NASA Task Load Index (NASA-TLX). Low target prevalence and faster display speed reduced hit rate, while display type did not produce a significant effect on hit rate. Responses to the NASA-TLX indicate that participants rated lower target prevalence as less physically demanding, faster display speed as more temporally demanding, and, notably, dynamic displays as less effortful, less mentally demanding, and less temporally demanding. The finding that participants deemed the dynamic display as less effortful could be attributed to the condition's predictable item movement and target onset location within the display (Alvarez, Konkle, & Oliva, 2007). This explanation is supported by previous research demonstrating that predictable item movement improves search efficiency through the reduction of necessary eye movements (Boot, Becic, & Kramer, 2009), while unpredictable item movement has been shown to decrease search efficiency and accuracy (Peltier & Becker, 2015). Considering the current study's results in-conjunction with previous research, we postulate that predictable item movement reduces the need for eye movements, decreasing the perceived difficulty of the visual search and potentially improving efficiency.

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Evidence from contralateral delay activity that proto-objects are a good approximation of real-world set size

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Decades of memory and visual search work demonstrate that increasing set size tends to decrease performance. Set size is easy to determine with simple stimuli, but how do you count the number of items in the real-world? Is a bowl of fruit one item, or many? Measures of clutter have been proposed as an alternative to counting items (Neider & Zelinsky, 2011). Clutter can be estimated by segmenting images into proto-objects (Yu et al., 2014), which predict human clutter rankings (Yu et al., 2013) and fixation density (Chen & Zelinsky, 2019). Contralateral delay activity (CDA; Vogel & Machizawa, 2004) measures the number of items maintained in visual working memory (Luria et al., 2016). Using data from Schmidt et al. (2014, Experiment 2), the current work assessed if the number of proto-objects in real-world stimuli, presented as target cues during a visual search task, affect CDA and later eye-movement metrics of visual search performance. Target cues were previewed for 400 ms, followed by a 1000 ms ISI in which CDA was assessed. The subsequent search array contained one target and three distractors from non-target basic level categories. Trials were separated into conditions based on whether targets had a low or high number of proto-objects. CDA in response to the target cue was greater (consistent with storing more items) when targets contained more proto-objects (p=.007).

Additionally, search performance showed that targets with more proto-objects elicited poorer guidance (initial saccades to the target), longer RTs, and longer target dwell times (all $p \leq .001$). We conclude that the number of target-related proto-objects predicts the resulting visual working memory load and later search performance in the context of real-world objects. Future work is needed to identify optimal methods of proto-object segmentation for set size prediction, and to test generalization to paradigms beyond search.

Poster Session G > Visual Search: Spatial, temporal, memory > Poster G91

Eye movements and interactions between numerical and physical size in visual search for digits

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In the size congruity effect (SCE), participants identify the “smaller” or “larger” digit among pairs of digits more quickly when the physical and numerical size (value) are congruent compared to incongruent. The SCE also occurs in visual search, and suggests that semantic (numerical size) and perceptual (physical size) information interact during visual processing of digits. We examined eye movements to investigate whether semantic and perceptual information interact at an early, perceptual stage of processing, or later, at a decision-related stage. We tracked participants’ gaze as they searched for congruent (e.g., a physically small 2 among large 8s and 9s) or incongruent (e.g., a physically large 2 among small 8s and 9s) target digits and reported their location (right or left side of the display). Early interaction may lead participants to experience conflict prior to attending to the target, resulting in longer time to first fixation (TFF) for incongruent compared to congruent targets. Alternatively, if interference occurs at a decision stage, participants may initially fixate on the target equally quickly (similar TFF) across conditions and experience conflict in incongruent trials only after attending to the target, leading to longer duration or number of fixations to incongruent targets. Results replicated the SCE in visual search and revealed longer TFF for incongruent compared to congruent targets, but no difference in the total duration of fixation or number of fixations on the target across conditions. These findings may be consistent with an early interference account; however, more fixations on distractor items on incongruent trials may have led to longer TFF due to conflict occurring during decisions to reject those distractors prior to fixation on the target. Follow-up work will explore the role of attention to distractors in this task and related implications for early vs. late interaction between physical and numerical size.

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Search for center-surround colored stimuli highlights peripheral vision processing limitations

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Peripheral vision processes information in parallel, and contributes to efficient visual search performance, with a signature RT function that increases logarithmically with set size. Recent work demonstrated that search efficiency when target and distractors differ along both color and shape can be predicted by search efficiency observed in single-feature search (color-only and shape-only search tasks). Following that logic, we conducted a set of experiments to investigate search efficiency when stimuli are defined as a combination of two colors, in a center-surround arrangement. In Experiment 1, we found that searching for the red-center/green-surround target among the reversed color distractors had larger RTs than searching among same center-color distractors, same surround-color distractors or irrelevant color distractors. Surprisingly, RT functions did not follow either a logarithmic nor a monotonic linear function in none of the distractor conditions. In Experiments 2-3, we decomposed the target and distractors by keeping the center or surround color blank and the results did follow logarithmic functions. These results demonstrate that although observers can process single-color objects in parallel, they struggle searching through two-color objects, indicating either a difficulty maintaining the center-surround target template in memory or a difficulty using peripheral vision to make target-distractor comparisons in two-color stimuli conditions. We ran three additional experiments to investigate this pattern of results. In

Experiment 4 , we tested the hypothesis that observers were using a singleton search strategy by instructing them to use that strategy. In Experiment 5, we reminded observers of the search target at the start of each trial. In both cases, we found evidence that participants were not using the target template but rather were relying on the singleton search strategy. However, when we changed the color configuration to two colors one above the other in Experiment 6, we once again found evidence of parallel efficient processing.

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Individual differences in crowding predict visual search performance

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Visual search is an integral part of human behavior, and has proven important to understanding mechanisms of perception, attention, memory, and oculomotor control. Thus far, the dominant theoretical framework posits that search is mainly limited by covert attentional mechanisms, comprising a central bottleneck in visual processing. A different class of theories seeks the cause in the inherent limitations of peripheral vision, with search being constrained by what is known as the functional viewing field (FVF). One of the major factors limiting peripheral vision, and thus the FVF, is crowding. We adopted an individual differences approach to test the prediction from FVF theories that visual search performance is determined by the efficacy of peripheral vision, in particular crowding. Forty-four participants were assessed with regard to their sensitivity to crowding (as measured by critical spacing) and their search efficiency (as indicated by manual responses and eye movements). This revealed substantial correlations between the two tasks, as stronger susceptibility to crowding was predictive of slower search, more eye movements, and longer fixation durations. Our results support FVF theories in showing that peripheral vision imposes an important limitation on visual search.

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Contrasting attentional processing in visual search, object recognition, and complex tasks

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Visual attention is known to be involved in task control, yet not much is known about the role of attentional processing in different tasks. Attention is often investigated in visual search, where the task is to localize an object in a scene, while another basic task is to recognize an object, where the attentional processing is largely unexplored. However, we propose visual attention being involved in multiple tasks differently and investigate how visual attention might operate in several complex tasks. The motivation comes from the complexity of real-world tasks. Typical is a continuous interplay between different basic tasks, like first searching an object, identifying it, using it, etc. Based on a recent neuro-computational model of visual attention (Beuth, Doctoral thesis, 2019; Beuth & Hamker, 2015, Vision Research), replicating a large set of neurophysiological data, we selectively disabled different mechanisms that altogether define attention in the general case, and measured performance drops. Analysis was performed on an image data base (COIL-100) and a real-world application (wafer inspection). For visual search, we found that the top-down amplification of specific objects and features is important, as well as the spatial suppression between different places. While for recognition, we diametrically found a significance for the spatial amplification, and for the feature-based suppression. Hence, we observed opposing influences and found out that visual attention operates diametrically in the localization and recognition task in the visual system. In more complex tasks (Object Substitution Masking), composed of visual search and recognition, we found an interplay takes place between both mechanisms, according to the phases of the involved processes. These results illustrate how visual attention may operate in two major task classes, and the model predicts how complex tasks can be solved based on these 'building' blocks to realize the complex task nature of our real-world.

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Changes in Viewing Behaviour in Healthy Aging and Amnestic Mild Cognitive Impairment

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Memory-related viewing behavior is diminished in older adults, and lacking in amnesic cases who have reduced integrity of the medial temporal lobe (MTL), including the hippocampus, a region involved in memory. Given the link between viewing behavior and memory, the present study investigates perturbations in eye movements as a consequence of declining MTL integrity with normal and abnormal aging. Younger adults, healthy older adults, and older adults with amnestic mild cognitive impairment (aMCI) participated in a scene viewing task in which they freely viewed images presented on the screen as their eye movements were monitored. Amnestic MCI is typically associated with volume declines in the MTL, specifically the hippocampus, and is associated with subjective and objective cognitive impairment. Therefore, this group may provide key understanding of how eye movements are perturbed due to abnormal aging. We analyzed eye movement metrics to quantify the manner and extent of scene exploration. A multivariate analysis, partial least squares (PLS), was used to test if the three groups differed on the eye movement metrics. PLS results revealed that the pattern of viewing for aMCI adults was associated with more gaze fixations, more saccades, more regions sampled, yet their effective area of exploration was limited (i.e., lower root mean square deviation), saccade amplitude was lower, and viewing entropy was higher. The opposite pattern was expressed by younger adults; older adults did not express either pattern. These results demonstrate that, even in the absence of an overt memory task, patterns of eye movements recorded during free viewing can be used to differentiate groups with varying integrity of memory-related brain regions. Such findings suggest that eye movements may reveal disturbances in the moment-to-moment formation of representations in memory.

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Feature distribution learning by passive exposure

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Humans can rapidly estimate the statistical properties of a group of stimuli, including their average, variability and even more complex aspects, such as their distributions. Studies of Feature Distribution Learning (FDL) have, for instance, shown that participants rapidly learn the full shape of a distractor distribution and can use it to improve visual search performance: response times (RT) are faster if the target-defining feature lies outside the previous distractor distributions. FDL is surprisingly rapid, requiring only a few trials, and markedly sensitive to different distribution types (e.g., Gaussian versus uniform). It is unknown, however, whether our perceptual system encodes feature distributions automatically through passive exposure —i.e., in the absence of an attentional task. In two experiments, we sought to answer this question. Participants performed blocks of trials with an initial exposure stage followed by a single search trial. In the exposure stage, they passively saw a series of displays of 36 lines that included one singleton (an oddly oriented line, Experiment 1) or no singletons (Experiment 2). In the search trial display, they had to report the location of an oddly oriented target. The orientations of the lines were determined either by a Gaussian or a uniform distribution. To measure FDL, we parametrically varied the orientation distance between the search target and the center of the exposed distractor distribution. We found evidence for FDL when search efficiency was high (e.g., RT<1 second) and the display contained a singleton (Experiment 1). Under these conditions, RT decreased as a function of the orientation distance between the target and the exposed distractor distribution. These results suggest that FDL can occur by passive exposure, provided an involuntary and task-irrelevant singleton selection process during exposure. This argues that FDL is not bound to the attentional selection process involved in an active visual search.

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Decision Making

Poster Session G > Decision Making > Poster G97

Efficient sensory encoding predicts robust averaging

View Poster | Visit me in Gather.Town Dolphin Room on Tuesday 8:00 am - 10:00 am EDT

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Ensemble perception is a perceptual integration process that computes the average feature of an array of visual stimuli. Recent evidence shows that the observer weights each of the elements in a display unequally when computing the mean: higher and lower weights are assigned to the elements with features close to (inlying elements) and further away (outlying elements) from the mean, respectively. The non-uniform weighting process, named robust averaging, has been taken as evidence against the optimal Bayesian behavior in perception. Here we show that robust averaging can be predicted by a Bayesian observer model constrained by efficient coding that assumes optimized sensory representation with respect to the stimulus statistics learned over the experiment. To test our model, we fitted the data from Li et al. (2017) in which subjects discriminated the average feature (orientation) of eight elements displayed in a circle relative to a reference element. Element features were sampled from Gaussian distributions with varying means and variances. Our model captured the key aspects of their reported data. Specifically, we predicted 1) higher weights for inlying than outlying elements, 2) overall higher weights in the condition with fixed than varied reference element within blocks, and 3) higher discrimination accuracy when the Gaussian distribution had a large generic mean (relative to the reference) and a small variance. In addition, our model replicated the signature of robust averaging reported in de Gardelle & Summerfield (2011), in which different stimulus features (color and shape) were used. Our modeling results suggest that robust averaging is attributed to the inhomogeneous encoding precision of inlying and outlying elements. Furthermore, they imply that efficient sensory representations of visual stimuli can be established on short timescale by learning the stimulus statistics over the course of a psychophysical experiment.

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Reported confidence is based on imprecision in visual cortical stimulus representations

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Virtually any decision people make comes with a feeling of confidence about its correctness. What cortical computations might underlie this sense of confidence? Recent Bayesian theories propose that confidence is computed (in part) from the degree of uncertainty in sensory information. However, direct neural evidence for this hypothesis is currently lacking. Here, we test this hypothesis in human cortex using a combination of psychophysics, fMRI, and computational modeling. Participants viewed gratings of random orientation (0-179 degrees), while their brain activity was measured with fMRI. Critically, no physical stimulus noise was added to the stimuli, as this could then act as an external cue to confidence. After the grating disappeared from the screen, observers reported the orientation of the grating as well as their level of confidence in this perceptual judgment. The uncertainty associated with stimulus representations in human visual cortex (V1-V3) was quantified using a probabilistic decoding approach (van Bergen, Ma, Pratte & Jehee, 2015; van Bergen & Jehee, 2018). We used this decoded uncertainty to compare the human data to simulated data from both a Bayesian observer, as well as two alternative models implementing heuristic strategies to confidence. As predicted by the Bayesian model, we found that reported confidence tracks the degree of uncertainty contained in visual cortical activity. More specifically, when the cortical representation of a stimulus was more precise, observers reported higher levels of confidence. We moreover discovered that activity in the Insular, Anterior Cingulate, and Prefrontal Cortex reflected both

this sensory uncertainty and reported confidence, in ways predicted by the Bayesian observer model. Altogether, this supports recent normative theories and suggests that probabilistic sensory information guides the computation of one's sense of confidence.

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Poster Session G > Decision Making > Poster G100

The Set Salience Bias in Ensemble Decision-Making

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When comparing two sets of items based on one visual property like size or position, we should be able to make a decision without influence from irrelevant visual features. However, across a collection experiments that asked subjects to compare the average value of two sets, seemingly arbitrary visual features like set luminance biased which set a subject chose. Each experiment had over 800 trials. For each trial, subjects were shown two sets of 20 items side-by-side and asked which set had the higher average vertical position or which set had the higher average size (the target feature). The difference between the averages varied by trial. Each experiment had a one target feature (position or size) and one distractor feature that varied the appearance of each set as a whole. Distractor features included contrast (100% vs 50%), set size (20 vs 12), shape (square vs circle), and filled vs outlined. Item width (100% vs 66%) was another distractor feature but only when position was the target. Fitting the responses to psychometric functions, each experiment found that subjects were biased to select the more visually salient set as having a higher average position or a larger average size. Despite subjects getting feedback after every trial for hundreds of trials, the bias persisted. Moreover, another experiment modulated the distractor contrast, which resulted in similar modulation of the bias strength. To counter the possible explanation that the bias is caused by subjects conflating the two features, additional experiments asked subjects to report the lowest average position or size. In these experiments, subjects were still biased towards the set with the more salient distractor feature (e.g., higher contrast or larger set size). The consistent direction of this bias even when inverting the task suggests a decision-making bias rather than a perceptual illusion.

Poster Session G > Decision Making > Poster G101

Cybersecurity and Fatigue: Does fatigue from visual contrast impact our ability to correctly classify emails?

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Email phishing schemes represent a constant threat to personal and organizational security. To combat this threat, it is critical to develop a firm understanding of the factors that affect email classification performance. One such factor might be fatigue. Work performance research shows that fatigue impairs information processing, shortens attention span, and slows reaction times. Studies have demonstrated that elevated screen use can induce fatigue that leads to such impairments (Jeong, 2012; Lin et al., 2008). Specifically, Bhattacharyya et al. (2014) showed that changes in text-background contrast induce fatigue. The current study examined whether fatigue impacts email classification performance. Participants first read a series of text-excerpts on a computer screen and answered comprehension questions, after which they classified 100 emails (4 blocks; 25 emails per block) as either legitimate or non-legitimate (50% legitimate; see Sarno et al., 2020). Additionally, we manipulated the text-background contrast of the initial reading task; the text was either black (high contrast/low-fatigue) or yellow text (low contrast/high-fatigue) on a white background. Somewhat surprisingly, we found that the high-fatigue group had higher accuracy (75.6%) than the low-fatigue group (66.4%; $p_{holm}= 0.002$). Participants performed better when classifying legitimate emails ($p< 0.001$). Additionally, the high-fatigue group had higher accuracy (75.3%) for non-legitimate emails than the low-fatigue group (48.7%; $p_{holm}< 0.001$). No group difference was found for legitimate emails ($p_{holm}= 0.285$). The low-fatigue group also misclassified non-legitimate emails as legitimate at a higher rate (50.6%) than the high-fatigue group (29.5%; $p= 0.005$). The data support fatigue's role in email classification performance, but in an unexpected way. Fatigue improves email classification accuracy, particularly for non-legitimate emails. We speculate that the high-fatigue task required participants to actively focus, which increased stress and boosted performance. It is also possible that the high-fatigue condition made participants more cautious, and subsequently changed participants' email classification criterion.

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The shape of metacognitive noise confounds metacognitive efficiency with confidence bias

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It is now widely appreciated that confidence ratings are corrupted by metacognitive noise. We recently suggested that the magnitude of the metacognitive noise increases with sensory evidence such that the highest confidence criteria are the noisiest (Shekhar & Rahnev, 2021, Psychological Review). This effect was captured by a new process model of confidence that predicts that increasing one's confidence – which is equivalent to using lower confidence criteria – should result in higher estimated metacognitive sensitivity. In order to test this predicted relationship, here we developed a new method of simulating a change of confidence by removing the highest or the lowest confidence criterion from existing data. Intuitively, removing the highest (vs. the lowest) confidence criterion leads to the confidence criteria becoming more liberal and thus simulates a situation where subjects make more judgments with high confidence leading to an overall increase in confidence. Since removing the highest (vs. the lowest) confidence criterion removes the criterion that is hypothesized to be the noisiest (vs. least noisy), we predicted that it would lead to higher estimated metacognitive sensitivity. We applied this manipulation to the data from three tasks from the Confidence Database (N > 400 in each) and we used meta-d' as the measurement for metacognitive sensitivity. Confirming to the model's prediction, we found that removing the highest (vs. the lowest) confidence criterion leads to an increase in both confidence and metacognitive sensitivity in all three tasks (all p's < 0.005). These results provide support for the notion that metacognitive noise increases with decision evidence, and point to an important confound between metacognitive sensitivity and confidence bias.

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Serial dependence is related to the task and not the stimulus

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There is a hot debate about the nature of serial dependence (SD), the tendency to judge stimulus features in a given trial as similar to the previous trial. It is often argued that SD reflects a mechanism to stabilize perception, combining features of similar stimuli over time. Here, we demonstrate that SD does not combine stimulus features at all, but only task-related information. We presented a random-dot kinematogram (RDK, 1000 ms, 90% coherence, radius of 1.25°) superimposed on a noisy Gabor patch (50% of contrast, spatial frequency of 0.33 cpd, noise ratio of 40%) leading to a fused stimulus. In each trial, the tilt of the Gabor and the motion were chosen independently. We pre-cued human participants to report either one of these features. In Experiment 1, the pre-cue indicated whether the Gabor or the motion orientation should be adjusted with the mouse. In Experiment 2, we also varied the RDK speed, and the pre-cue indicated which task to perform (adjustment task on the Gabor orientation or binary speed discrimination task on the RDK). First, SD effects were identical, independent of whether the target stimulus feature was the same as in the trial before (e.g., RDK to RDK) or different (e.g., RDK to Gabor). Second, there was no SD for non-target features. Third, SD in orientation occurred only when the previous task was about orientation and not speed. These results suggest that SD is tied to task features and not to stimulus features (e.g., the 'orientation' independently of other elementary features). Our results do not support the notion that SD is linked to stabilizing perception.

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Do we perceive the world differently if we need to evaluate our percept? – an EEG study

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The information available to our senses is limited, making multiple interpretations possible. The brain decides for the most probable interpretation to provide stable and reliable percepts. Depending on the quality of the sensory information, this perceptual decision can become difficult. Recent studies indicate the existence of a meta-perceptual evaluation system, rating the reliability of perceptual decisions. In the current study, we investigated whether the necessity to explicitly report reliability of the perceptual decision changes processing of the observed stimulus. Methods: We presented ambiguous and unambiguous Necker cubes in random order. In Condition 1, participants indicated the perceived 3D cube orientations. In Condition 2, participants additionally reported the confidence of their perceptual decision. 17 participants were included (24 to 32 years; 12 females). All participants had a corrected vision of at least 0.8 visual acuity and no neurological problems or eye diseases. EEG was recorded with 32 active silver/silver-chloride electrodes. EEG data was sorted for condition and stimulus and averaged to ERPs. Results: We found overall larger ERP amplitudes in Condition 1 compared to Condition 2, starting with an occipital component at 104 ms (E1), followed by a frontopolar component at 172 ms (E2), a parietal P300-like signal at 324 ms (E3), and a temporally sustained positivity lasting for more than 400 ms (E4). Discussion: The a priori knowledge about the evaluation task may amplify visual processing units (E1). Perceptual decision and top-down evaluation steps may start immediately after the lattice-gestalt construction (E2). In Condition 2 the evaluation result needs to be kept in working memory until the evaluation response is executed 1600 ms after stimulus onset (E4). In summary, the necessity to rate our perceptual decisions starts to alter perceptual processing remarkably early. We seem to perceive the world differently if we need to evaluate our percepts.

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Dissociating bias and precision of perceptual decision making in parietal and frontal cortices with TMS

View Poster | Visit me in Gather.Town Dolphin Room on Tuesday 8:00 am - 10:00 am EDT

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Numerous cortical areas are active while participants relate together visual and egocentric vestibular information. Although dorsal parietal and medial prefrontal cortical activity correlate with visual-vestibular task performance, it is not clear what causal role these dorsal cortical areas may play in the human. We used transcranial magnetic stimulation (TMS) to interfere with activity in parietal or medial prefrontal cortices in groups of between 16-20 healthy people, while they performed the subjective visual vertical (SVV) task. Participants reported with a button press whether a flashed line was tilted counterclockwise or clockwise of true vertical. By fitting psychometric functions, we measured perceptual performance in terms of bias (also referred to as accuracy) versus precision (or sensitivity, threshold, reliability, sigma). In the first study, participants were sorted into two groups of 16 according to their baseline bias at SVV i.e. those with either a slight counterclockwise versus clockwise bias when judging a line to be truly vertical. Right parietal TMS facilitated verticality perception, reducing the difference between groups - affecting bias, with no effect on precision. ERPs suggested that the behavioural TMS effect occurred through normalizing individual SVV biases. No such effects occurred with control stimulation and tasks. In the second study, to ensure a high perceptual demand (putatively necessary to demonstrate a dorsal medial involvement) SVV lines were presented inside pop-out targets within a visual search array. Perceptual performance was analysed before and after theta-burst TMS stimulation of the medial frontal cortex, a control site, or no stimulation, in three groups of 20 people. Medial frontal stimulation improved the precision of verticality judgments with no effects on bias. Taken together, we suggest that human dorsal cortical regions play roles in SVV perception which are causal, dissociable, and attentional.

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Without adaptive stimulus sampling, comparison-of-comparison tasks skew perceptual bias estimates

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Measuring perceptual bias is method-dependent. When judging perceived stimulus size, we previously found a traditional two alternative forced choice (2AFC) task produced bias estimates that were significantly greater than a novel perceptual matching (PM) task, a variant of a comparison-of-comparisons (CoC) task (e.g. Finlayson, Papageorgiou, & Schwarzkopf, 2017). CoC tasks are thought to better control for decisional criterion issues than 2AFC because it constrains stimuli to differ only in the stimulus parameter of interest (Morgan, Melmoth, & Solomon, 2013; Jogan & Stocker, 2014; Patten & Clifford, 2015). Using the Ebbinghaus illusion, here we aimed to test if decisional bias could be driving the difference in bias estimation between 2AFC and PM. In Experiment 1 (n=7), we collected confidence reports alongside each 2AFC judgment and estimated perceptual bias as the point of maximum uncertainty, because metacognitive bias estimates have also been suggested to control for criterion shift (Gallagher, Suddendorf, & Arnold, 2019). We found no difference between 2AFC and metacognitive estimates, while PM estimates were significantly lower than both. In Experiment 2 (n=22), we tested if PM or 2AFC tasks were better at capturing true perceptual bias. We varied test target sizes using idiosyncratic bias estimates from PM and 2AFC and found that 2AFC estimates were superior in nulling the Ebbinghaus illusion. Subsequent simulations revealed that CoC tasks skew bias estimates because 2AFC requires judgment against the position of the true bias, while CoC involves judging the distances from the true bias. In Experiment 3 (n=32), we showed that this dependency can be corrected via adaptive stimulus sampling. On average, adaptive PM produced comparable bias estimates to 2AFC and both methods were equally good at nulling the Ebbinghaus illusion.

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Brain connectivity profiles associated with perceptual task performance

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Over the last several decades, extensive research has uncovered the brain areas that support many perceptual tasks. However, surprisingly little is known about how the brain connectivity profile during task execution is related to task performance. Here we collected functional MRI (fMRI) data from 50 human subjects performing a simple perceptual task with confidence, and investigated how the functional connectivity profile while engaging on a task is related to behavioral performance. Specifically, functional connectivity was estimated based on the 200 brain regions identified in the Schaefer atlas. We found that higher accuracy is associated with increased modularity, or the extent to which brain regions combine to form communities, but was unrelated to reaction time (RT), confidence, or metacognitive efficiency. Further, we examined how these behavioral variables were related to the connectivity between large brain networks. The results revealed that subjects who exhibited faster response times had stronger connectivity between the dorsal and the ventral attentional network and slower responses were associated with stronger connectivity between the ventral attention and limbic networks. In addition, confidence was associated with the strength of connectivity between the somatomotor and both the default mode and dorsal attention networks, consistent with theories of action-related influences on confidence. Surprisingly, global brain connectivity was not related to metacognitive efficiency, suggesting that the quality of one's metacognition may not depend on global brain dynamics. These results demonstrate that different components of task performance depend on different brain connectivity profiles and provide insight into the mechanisms behind simple perceptual tasks.

Poster Session G > Decision Making > Poster G108

Perceptual decisions under stable visual input: absence of serial dependence and the build-up of adaptation

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In serial dependence (SD), perceptual decisions are biased toward stimuli seen in the recent past. It is believed that SD originates from a perceptual prior that the world is stable and stimuli are correlated in time. Often, however, SD is observed in conditions that deviate from this prior —i.e., in tasks involving uncorrelated stimuli. It is therefore unclear to what extent perceptual priors are crucial for SD. If there is such a prior, one would expect larger SD for "stable", i.e., correlated, streams of stimuli but reduced or absent SD for highly variable stimuli. Here, we tested this idea by manipulating the stability of visual features in an orientation adjustment task. Twenty human observers were presented with sequences (4-12 stimuli) of brief (200 ms), low-contrast (10%), and noisy (SNR = .5) Gabor stimuli and were asked to reproduce the orientation of the last Gabor. In separate conditions, we varied the transition probabilities between the orientations in the sequence. In the Stable condition, Gabor stimuli were slightly fluctuating around a common orientation signal. In the Volatile condition, Gabor stimuli could drastically change orientation in each trial. We measured SD as the deviation of errors toward or away from the preceding orientation. We found only a weak SD in Volatile trials but no SD in the Stable condition. Rather, Stable trials revealed the build-up of adaptation-like repulsive aftereffect. Robust SD occurred only for the orientation reported in the previous trial, independently of the condition. Our results cast doubts on the involvement of perceptual priors in SD and are more supportive of SD being the byproduct of decision- and memory-related processes. Although they are typically considered a confound in SD studies, we argue that repulsive aftereffects, rather than SD, are the stereotyped and immediate reaction of our perceptual system to stable visual input.

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Poster Session G > Decision Making > Poster G109

Serial dependence and representational momentum in single-trial perceptual decisions

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The human brain has evolved to predict and anticipate environmental events from their temporal dynamics. Predictions can bias perception toward the recent past, particularly when the environment contains no foreseeable changes, but can also push perception toward future states of sensory input, like when anticipating the trajectory of moving objects. Here, we show that perceptual decisions are simultaneously influenced by both past and future states of sensory signals. Using an orientation adjustment task, we demonstrate that single-trial errors are displaced toward previous features of behaviorally relevant stimuli and, at the same time, toward future states of dynamic sensory signals. These opposing tendencies, consistent with decisional serial dependence and representational momentum, involve different types of processing: serial dependence occurs beyond objecthood whereas representational momentum requires the representation of a single object with coherent dynamics in time and space. The coexistence of these two phenomena supports the independent binding of stimuli and decisions over time.

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Poster Session G > Decision Making > Poster G110

Decreases loom larger than increases: A perceptual account for loss aversion

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Loss aversion is a cognitive bias where the pain of losing monetary value is greater than the pleasure of gaining the same value. Despite decades of research in loss aversion, the underlying mechanism remains elusive. Here we propose that loss aversion can be explained by a perceptual bias where decreases are overestimated than increases of the same magnitude. To test this account, we showed participants two displays of dots in succession. The first display contained 100 dots. The second display contained 20 to 90 dots by increments of 10, or 110 to 180 dots by increments of 10. After seeing the two displays, participants estimated the number of dots that changed. In our analysis, we paired a decreasing trial (e.g., from 100 to 20) with an increasing trial (from 100 to 180) based on the same magnitude of change. We aimed to examine perceived numerosity change when the number of dots decreased or increased for the same amount. Participants overestimated the number of dots that changed in decreasing trials than that in increasing trials, despite identical changes in both directions (Exp1). We replicated this finding by presenting the two displays simultaneously side by side (Exp2), by expanding the numerosity range from 100 to 900 dots (Exp3), by reversing the positions of the two displays (Exp4), when the language of increasing and decreasing was framed differently (Exp5), and when the positions of the two displays were randomized (Exp6). These results reveal a robust perceptual asymmetry where observers perceive a larger change in decreasing patterns than in increasing patterns despite an equal change in magnitude. This perceptual asymmetry can explain loss aversion where losses are overweighted than gains of the same magnitude. The current findings contribute to the broader question of how perceptual biases underlie cognitive biases.

Visual Search: Spatial, temporal, memory

Poster Session G > Visual Search: Spatial, temporal, memory > Poster G111

Did you find it? Visual search tends to be faster when applying saliency-aware subtle scene modulation in VR-based realistic scenario

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Visual search as a daily task becomes particularly challenging when the time to find the target is limited. In a pilot study, we investigate whether a subtle modulation of visual content considering the scene saliency map can improve visual search performance in terms of the search time and proportion of failure to find the target within a limited time. To do so, a set of naturalistic omnidirectional images were displayed in virtual reality (VR) with a search target being overlaid on the visual scene at a random location. During the experiment, each of five participants performed a visual search task in this virtual environment with an ultimate goal to find the search target as soon as possible within 20 seconds. By subtle modulation of the visual content we intended to redirect the observer's attention from salient regions of the scene, and, that way, enable the participant to find the search target faster. The scenes were modified applying blur, where blurring strength was spatially varied based on the saliency maps computed for the displayed omnidirectional images before the experiment. Specifically, the most salient regions of the scenes were blurred using a convolution of the original image with a Gaussian kernel. The maximal strength of blur was varied via different standard deviations of the Gaussian filter, defining three different experimental conditions. The mean search time, as well as the proportion of trials where participants failed to find the target, were compared among different strength values of a blur. Using linear mixed-effect model analysis, a significant decrease of search time as well as a significant reduction of the proportion of failed trials, as a function of blur strength, were found. Thus, this pilot study shows a possibility to improve visual search performance in realistic 3D scenes by applying a subtle saliency-aware scene modulation.

Acknowledgements: Integrative Augmented Reality (I-AR) intramural funding of the University of Tuebingen, Germany

3D Perception: Cue combination

Poster Session G > 3D Perception: Cue combination > Poster G121

The comparison makes a difference: What to choose when measuring the Just Noticeable Difference of a 3D cue-conflicting standard

View Poster | Play Video | Visit me in Gather.Town Egret Room on Tuesday 8:00 am - 10:00 am EDT

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The Just Noticeable Difference (JND) is a common measure used to investigate models for 3D cue combination. It is typically assumed that the JND reflects the variance in the 3D shape estimate from depth cues when viewing an object. Although it is straightforward to measure the JND for a cue consistent standard by using a cue consistent comparison, it is less obvious for a cue inconsistent standard. Using a cue consistent comparison, as some experimenters have done, will lead to a measured JND that reflects the two different variance structures of the standard and comparison instead of the desired JND that reflects only the estimation variance associated with the standard. In this study, we seek to show that the comparison stimulus must have the same cue conflicts as the standard when measuring the JND. To accomplish this, we employ two crucial conditions when measuring the JND of a cue inconsistent standard: one where the comparison is cue consistent and the second where the comparison is cue inconsistent with the same cue conflicts as the standard. Our results show that the measured JND from these conditions are significantly different yet consistent with the predictions of the Maximum Likelihood Estimation (MLE) model for 3D cue combination. This study demonstrates that it is important to strategically choose the type of comparison depending on what variance structure the JND is expected to reflect.

Acknowledgements: This work was supported by NSF 5260297

Poster Session G > 3D Perception: Cue combination > Poster G122

Casting a Shadow on the Ponzo Size illusion

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In the classic Ponzo illusion the perceived size of a stimulus is affected by lines in the background suggesting a linear perspective in depth. A stimulus or object close to the vanishing point appears further away and therefore larger than an object of the same size placed in the foreground. However, introducing a static or moving shadow cast by the object creates the impression that the object floats above the ground, thereby changing perceived size (Yonas, Goldsmith & Hallstrom, 1978; Kersten, Mamassian & Knill, 1997). Here we investigate how strong a cast shadow of a stimulus ball affects perceived size. A total of N=38 observers participated in an online study with a 4 by 2 within-subjects design. We tested the effect of four vertical shadow offsets (0, 46, 92, and 184 pixels) and two positions of the reference ball (64, and 164 pixels). An analysis of variance (ANOVA) with repeated measurement revealed that shadow offset ($F(3,111)=13.17$, $p<.0001$, partial eta squared=0.263) as well as reference position ($F(1,37)=30.08$, $p<.0001$, partial eta squared=0.448) had a statistically significant effect on perceived size. The interaction was not significant ($F(3,111)<1$). The average observer seems to base their size judgments entirely on the relative position of the cast shadows because this disambiguates the location of the stimulus and reference ball in the 3D scene. A linear mixed model (package lme4 in R) showed considerable individual variability for both effects but confirmed that vertical offsets of cast shadows systematically changed the Ponzo size illusion. We conclude that the relative position of stimulus and reference shadow rather than the relative position of stimulus and reference ball determines perceived size.

Poster Session G > 3D Perception: Cue combination > Poster G123

Interpretation of Depth from Scaled Motion Parallax in Virtual Reality

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Humans use visual, vestibular, kinesthetic and other cues to effectively navigate through the world. Therefore, conflict between these sources of information has potentially significant implications for human perception of geometric layout. Previous work has found that introducing gain differences between physical and virtual head movement had little effect on distance perception. However, motion parallax is known to be a potent cue to relative depth. In the present study, we explore the impact of conflict between physical and portrayed self-motion on perception of object shape. To do so we varied the gain between virtual and physical head motion (ranging from a factor of 0.5 to 2) and measured the effect on depth perception. Observers viewed a ‘fold’ stimulus, a convex dihedral angle formed by two irregularly-textured, wall-oriented planes connected at a common vertical edge. Stimuli were rendered and presented using head mounted

displays (Oculus Rift S or Quest in Rift S emulation mode). On each trial, observers adjusted the angle of the fold till the two joined planes appeared perpendicular. To assess the role of stereopsis we tested binocularly and monocularly. To introduced motion parallax, observers swayed laterally through a distance of 30 cm at 0.5 Hz timed to a metronome beat; this motion was multiplied by the gain to produce the virtual view-point. Our results showed that gain had little effect on depth perception in the binocular test conditions. Using a model incorporating self and object motion, we computed predicted perceived depths based on the adjusted angles and then compared these with each observer's input. The modelled outcomes were very consistent across visual manipulations, suggesting that observers have remarkably accurate perception of object motion under these conditions. Additional analyses predict corresponding variations in distance perception and we will test these hypotheses in future experiments.

Acknowledgements: Thanks to NSERC Canada for support under a Collaborative Research and Development grant in partnership with Qualcomm Canada and to the Vision: Science to Applications (VISTA) program partly funded by the Canada First Research Excellence Fund.

Poster Session G > 3D Perception: Cue combination > Poster G124

Effects of cue integration on three-dimensional shape from shading

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Shadows can serve as a strong cue for 3D shape perception and lead to illusions of depth perception. In orthographically captured satellite images and aerial photographs, shadows serve as the primary depth cue, but this is usually accompanied by various other secondary ones, such as color, texture and relative size. In line with the literature, we have previously demonstrated that when such secondary cues are removed, i.e., a terrain is represented only based on shading, varying the light direction can lead to dramatic differences on how depth is perceived: Specifically, the south-eastern illumination leads to total reversal of depth perception, whereas north-western illumination angles lead to nearly zero reversal effect. This illusion has been named terrain reversal (or relief inversion) effect. Here we examine effects of cue integration, specifically the contributions of texture, color and stereoscopic viewing to the terrain reversal effect in two controlled lab experiments (n=27 and n=33, counterbalanced for biological sex and expertise). Our findings suggest photo-textures help bypassing the illusion, however, curiously grayscale more than color textures. Stereo also helps bypassing the illusion to some degree. Both of which we attribute to participants recognizing land cover elements, specifically because expert participants can bypass the illusion more often than others, and more often with satellite images than with shaded relief maps. To verify if this is indeed the case, eye movement data was also collected in these experiments to better understand why some participants are able to bypass the illusion more than others.

Poster Session G > 3D Perception: Cue combination > Poster G125

Just Noticeable Differences in 3D Shape Perception: A Measure of Estimation Noise or Cue Gain?

View Poster | Play Video | Visit me in Gather.Town Egret Room on Tuesday 8:00 am - 10:00 am EDT

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The present study sought to test two fundamentally distinct interpretations of the Just Noticeable Difference (JND) for depth discrimination. According to the widely accepted Bayesian Maximum Likelihood Estimation (MLE) model of 3D processing, the JND measures the standard deviation of the noise corrupting a depth estimate. The Intrinsic Constraint (IC) model of cue integration alternatively suggests that the JND is the result of task related decision noise rather than noise directly corrupting the depth estimate. According to this account, the JND is inversely proportional to the slope, or gain, of the perceptual function relating physical depth to perceived depth. To test this novel interpretation, we tested depth discrimination with a classic 2-Interval Forced Choice task in which the gains of a fixed standard stimulus and varying comparison stimulus could either have a High or Low value, or, according to Bayesian models, High or Low reliabilities. Bayesian models predict that the JND should depend on both the reliability of the standard and comparison stimuli. However, according to the IC model, the JND only depends on the gain of the comparison stimulus, and therefore there should be no difference between conditions where the comparison has the same gain. Empirical results with texture stimuli closely align with the IC predictions. In conclusion, since JNDs do not measure the magnitude of the

noise of 3D estimates as assumed by the Bayesian approach, these findings lead to a radically different interpretation of previous depth discrimination data.

3D Perception: Shape

Poster Session G > 3D Perception: Shape > Poster G126

Depth perception from successive occlusion

View Poster | Play Video | Visit me in Gather.Town Egret Room on Tuesday 8:00 am - 10:00 am EDT

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Occlusion of one object by another is one of the strongest and best-known pictorial cues to depth. However, it has been suggested that, in addition to a cumulative sense of depth, successive occlusions of previous objects by newly presented objects can give rise to illusory motion in depth (Engel, Remus & Sainath, 2006). Engel and colleagues (2006) found that a stacking disk stimulus, where each disk occludes a previous disk in a pile, generates a strong sensation of the stack moving towards the observer. While the perceived motion associated with this illusion has been studied, the resultant depth percept has not. To investigate if the successive introduction of occluding objects affected the perceived depth of a stacked disk stimulus, we compared two conditions. In one, participants were presented with two static piles of disks, while in the other, participants viewed one static and one stacking pile of disks. In both conditions, we presented 20 disks in one pile and a range of disks in the other using a method of constant stimuli. Participants indicated which pile appeared taller. The proportion of 'taller' responses were fit with cumulative normal psychometric functions from which we calculated points of subjective equality for the number of disks in each pile. We found static piles with the same number of disks appeared approximately equal in height. In contrast, the successive presentation of disks in the stacking condition appeared to enhance the perceived height of the stack - fewer disks were needed to match the static pile. Surprisingly, we also found just-noticeable differences varied between conditions: the task was easier when participants compared stacking vs. static piles of disks. Our results suggest that successive occlusions generate a greater sense of height than occlusion alone, and that dynamic occlusion may be an underappreciated source of depth information.

Acknowledgements: This work was supported by VISTA (Vision: Science to Applications).

Poster Session G > 3D Perception: Shape > Poster G127

Does the vertical-horizontal illusion explain over-estimation of perceived step height?

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In the vertical-horizontal illusion (VHI) observers overestimate the length of a vertical line relative to a horizontal especially when presented in a 'T' configuration. This illusion his has been used to accentuate the perceived height of steps with a vertical grating on the riser and a step-edge highlighter forming the horizontal bar. Patterned steps with the edge highlighter are typically compared to blank steps. Consequently, other effects may contribute to misperceived height including aggregation of the thick highlighter into the step height, and the filling of the patterned step with modulations (filled intervals appear larger). Various configurations of the VHI were tested including vertical luminance gratings (L) and second-order modulations of contrast, CM; orientation, OM; and spatial frequency, FM. Over 3 experiments, observers were asked to compare the apparent height of gratings with that of either filled, unmodulated rectangles or unfilled rectangles. Rectangles were presented alone or as part of a step with a highlighter. Highlighters sometimes matched the properties of the grating, sometimes not, and where sometimes separated from the gratings by a thin line. Observers undertook 2ifc judgements indicting which of a test or standard rectangle appeared taller. All gratings except FM appeared taller when presented in the step configuration with a contiguous highlighter matching the properties of the grating. However, this effect was greatly reduced when a thin line separated the grating from the highlighter and abolished when the highlighter did not match the grating. In the rectangle conditions, all cues except FM appeared taller than blank rectangles and L and CM appeared taller than filled-unmodulated rectangles. In conclusion, the ability of vertical stripes and edge-highlighters to accentuate step height may be due to aggregation of the highlighter

into the grating and filled interval effects. Further, second-order CM and OM modulations produce a similar illusion.

Poster Session G > 3D Perception: Shape > Poster G128

Regions of High Curvature Help to Stabilize the Perception of 3D Shape

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There is considerable evidence that the visual perception of 3D shape from shading can be influenced by the pattern of illumination. Some experiments have shown that changes in illumination can have dramatic effects on apparent 3D shape, whereas others have shown that these effects are relatively modest. One possible factor that may modulate these results is the 3D geometry of the depicted objects. The central hypothesis of the present experiment is that regions of high curvature on a surface provide perceptual landmarks that can help to stabilize shape perception over changes in illumination or materials. The stimuli were all constructed from plane-faced polyhedra that were subjected to varying degrees of smoothing that reduced the curvature of the polyhedral edges, and these objects were illuminated from either left or right. Their 2D images were judged using two different response tasks: a gauge-figure adjustment task, in which observers estimated the local surface orientation at designated probe points; and a near-point task, in which they marked points on the surface that appeared to be the nearest points in depth. The results suggest that regions of high curvature do indeed stabilize observers' 3D shape perceptions. As the curvature of the polyhedral edges decreased, this produced increased perceptual distortions relative to the ground truth, and the effect of illumination direction on perceived shape was magnified as well.

Acknowledgements: National Science Foundation (BCS-1849418)

Poster Session G > 3D Perception: Shape > Poster G129

The perception of average slant is biased in concave surfaces

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While much is known about our perception of surface slant for planar surfaces, less attention has been paid to our ability to estimate the average slant of curved surfaces. The average slant across a surface with symmetric curvature (a parabolic surface) and globally slanted about its axis of symmetry is equivalent to that of a planar surface slanted by the same degree. Therefore, if symmetrically curved surfaces are perceived accurately, observers’ estimates of their average surface slant should be the same as for an equivalently slanted planar surface. Here we evaluated this prediction using a 2-alternative forced choice slant discrimination task. Observers (n=10) viewed a standard 15° (top-away) slanted planar surface and a comparison surface that varied in slant between 7.5° and 22.5°; both were presented stereoscopically and textured with a Voronoi pattern. In separate conditions, the comparison surface was either planar, or parabolically curved (peak displacement = 0.15m) about its axis of rotation in a concave or convex direction. Observers consistently underestimated the average slant of the concave comparison surface relative to the planar surface. This bias is predicted by the effect of curvature modulating the degree of foreshortening in the perspective projection of a slanted surface. Perspective projection also predicts overestimation of average slant in convex surfaces, however we found no such bias. We propose that imprecision in the estimation of average slant in curved surfaces, relative to planar surfaces, makes them more susceptible to the commonly reported frontoparallel bias (slant underestimation). This bias may counteract the predicted overestimation of average slant in convex surfaces. Taken together, our modelling and psychophysical results indicate that curvature modulates the pattern of foreshortening of globally slanted surfaces, which biases the estimation of average slant. This, in turn, may lead to systematic errors in our interaction with curved surfaces.

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Poster Session G > 3D Perception: Shape > Poster G130

Depth percepts from monocular self-occlusions in 3D objects

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To date, the impact of monocular half-occlusions on depth perception has been studied almost exclusively in the context of foreground/background occlusion where, when viewing a stimulus binocularly, a surface occludes part of the background in one eye. However, monocular regions also arise from self-occlusion where an object occludes regions within itself. Previous research has shown that in two-surface arrangements the size and texture of the monocular region impacts the perceived depth between the occluder and the occluded region. In the case of self-occlusions, misinterpretation of monocular regions could result in distortions in the perceived 3D form of an object. Here we evaluate depth percepts in the presence of monocular self-occlusions for 3D objects. Specifically, we assess the impact of i) texture gradients within the occluded region and ii) object shape from binocular disparity, on the perceived extent of the object in depth. Stimuli were textured half-cylinders rendered with perspective projection and viewed on a mirror stereoscope. Perceived depth was assessed using a magnitude estimation task. Our results show that inconsistent monocular texture gradient information in self-occlusions does not influence depth estimates when familiar object shape from disparity is present. However, when observers are unable to use binocular disparity to extrapolate 3D shape, they do rely on 2D texture cues to make depth estimates. Under these conditions, when monocular texture is inconsistent with the binocular texture, depth is significantly underestimated. We conclude that, unlike two-surface occlusions, the visual system weighs depth information from self-occlusions depending on the availability of additional information about 3D object shape.

Acknowledgements: VISTA (Vision: Science to Applications)

Poster Session G > 3D Perception: Shape > Poster G131

Mental geometry of three-dimensional size estimation in pictures.

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It is essential for humans to estimate the size and pose of objects in a scene to successfully function in the visually oriented world. We show that the classical problem of three-dimensional size (3D) perception in pictures can be explained by comparing human performance to the optimal geometrical solution. There exists a single viewpoint from which a photograph forms the same retinal image as the 3D scene, but retinal projection of size and shape is distorted from the real scene as the photograph is seen obliquely. We previously showed that size and shape inconstancy for the real scene results despite observers using the correct geometric back-transform, if the retinal image evokes misestimation of the viewing elevation (Akihito & Zaidi, 2020). Here, we examine how observers estimate 3D sizes in four different oblique views of pictures of objects lying on the ground in 16 different poses. Compared to estimates for the real scene, in obliquely viewed pictures, lengths of objects were seriously underestimated at fronto-parallel poses, but there were almost no changes for objects pointing at or away from the viewer. The inverse of the projection function for the length of the object gives the optimal correction function inferring correct 3D length if viewing parameters, such as viewing elevation and azimuth, are estimated correctly. Empirical correction functions had similar shapes to optimal ones, but with lower amplitude. Measurements revealed that observers systematically underestimated the viewing azimuth, similar to the fronto-parallel bias for object pose perception (Koch, Baig, & Zaidi, 2018). A model that incorporates misestimations of viewing elevation and azimuth into the geometric back-transform function provided good fits to observers' estimates for 3D lengths from oblique views. These results add to accumulating evidence that observers use internalized geometric knowledge to perceive poses, sizes, and shapes in 3D scenes and their pictures.

Poster Session G > 3D Perception: Shape > Poster G132

Human judgments of relative 3D pose of novel complex objects

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A 3D object seen from different viewpoints can elicit vastly different retinal images. Differences between views depend on object geometry and initial pose, rendering relative pose estimation computationally challenging. Still, humans can easily judge object identity across views and estimate the relative pose between them. Here, we sought to measure how accurately observers can estimate pose similarity for 3D objects, and how these judgements are influenced by object geometry and changes in its retinal projection. We first mapped out human judgements of relative viewpoints using a multi-arrangement task. On each trial, observers (N=16) were asked to spatially arrange 31 views of one of three novel or three familiar 3D objects by viewpoint similarity. The resulting arrangements broadly matched ground-truth viewpoint differences with deviations that were consistent across observers (i.e. representational similarity analysis revealed correlations with ground-truth below the noise ceiling across objects). We implemented several candidate computational models, based on 2D image features or object geometry, and evaluated their ability to predict human judgements. Strategies using 2D features failed to account for human data. However, a metric based on the union and intersection of visible surface area across views (‘Surface IoU’) predicted human judgments on par with ground-truth. In order to maximise our power to differentiate between candidate strategies, we selected triads of viewpoints for individual objects over which pairs of models strongly disagreed (e.g. where similar changes in viewing angle produced very different changes in image pixels). We presented these triads in a two-alternative forced-choice experiment in which participants judged which of two views appeared closest to a target view. Across triad judgements and free arrangements, we gathered a rich dataset of human viewpoint perception for many objects and viewpoints that allows us to evaluate the ability of computational models to predict human strategies for judging relative viewpoint.

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3D Perception: Stereopsis, models and mechanisms

Poster Session G > 3D Perception: Stereopsis, models and mechanisms > Poster G133

Inverse graphics explains population responses in body-selective regions of the IT cortex

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Vision does not merely detect and recognize patterns and contours, but makes rich inferences about objects and agents including their three-dimensional (3D) shapes and configurations. Current modeling approaches based on deep convolutional neural network (DCNN) classifiers can explain aspects of neural processing, but they do not address how perception can be so rich and they typically do not provide an interpretable functional account of neural computation. To address these shortcomings, we take a different approach based on “efficient inverse graphics” (EIG), instantiating the hypothesis that the goal of visual processing is to invert generative models of how 3D scenes form and project to images. Instead of classification, we use DCNNs to build inference networks that invert generative scene models. EIG meets the functional goal of quickly computing rich 3D percepts and provides an interpretable reverse-engineering account of biological computation in the language of objects and generative models. We tested this approach in body perception: Two macaques, EIG and state-of-the-art DCNN classifiers saw images of monkey bodies that varied in shape, posture and viewpoint. EIG is designed to recover these variables from the images in an articulated 3D generative model, whereas the classifiers discriminated between object identities or body postures. Using representational similarity analysis, we compared layer activations of EIG to population-level activity obtained from single-cell recordings in body-selective regions of the inferotemporal cortex. Similarity matrices arising from the EIG layers were highly correlated with the neural similarity matrices. EIG explained neural activity significantly better than the classification networks ($p<.05$), which additionally failed to reproduce the key qualitative patterns observed in the data. These results provide an integrated account of how in the ventral stream, raw sense inputs are transformed into percepts of objects and agents, spanning the neural and cognitive levels of analysis, through the computation of inverse graphics.

Poster Session G > 3D Perception: Stereopsis, models and mechanisms > Poster G134

Feedforward-Feedback-Verity-reWeight (FFVW) and perceptual impact of contrast-reversed binocular dot-pairs in random dot stereograms

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In a random-dot stereogram (RDS), depth is by images presented to left and right eyes that comprise interocularly corresponding random black and white dots. The spatial disparities between the binocularly corresponding dots determine the object depths. If the dots are contrast-reversed, such that a black dot in one eye corresponds to a white dot in the other, disparity-tuned neurons in the primary visual cortex (V1) respond as if their preferred disparities become non-preferred and vice versa, reversing the disparity sign reported to higher visual areas. Humans cannot perceive the reversed depth in central vision. We demonstrate that, in central vision, reversed depth signals can augment or degrade depth perception in noisy RDSs when contrast-reversed and contrast-matched dots are mixed. When the reversed depth signals and the normal depth signals from the contrast-matched dots are congruent with each other, augmentation occurs; when they are incongruent with each other and when the RDS images are sufficiently brief, degradation occurs. These findings are consistent with the FFVW process, its feedback-Verify-reWeight component disambiguates noisy and ambiguous inputs from V1. Through an analysis-by-synthesis computation, this top-down feedback vetos misleading V1 signals, including, in certain situations, the reversed depth signals. When the RDS is viewed too briefly to allow time for feedback, augmentation or degradation works by adding, respectively, the congruent or incongruent, reversed signals to the normal signals in the feedforward direction. With a sufficient viewing duration for effective feedback, the feedback veto removes the degradation on the percept of the normal signals when the reversed and normal signals disagree, or, when the normal depth signals are absent, makes the reversed depth imperceptible. Meanwhile, the analysis-by-synthesis in the feedback process also fills in or corrects imperfect signals, allowing the reversed signals, when congruent with the normal depth signals, to augment the percept of the latter.

Acknowledgements: Funding by the University of Tuebingen and Max Planck Society

Face Perception: Neural mechanisms

Poster Session G > Face Perception: Neural mechanisms > Poster G136

Brain connectivity measures for holistic mechanisms of face perception

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Face perception is believed to involve two types of processes. When the face is presented normally, separate face features are expected to integrate into a global whole (i.e., holistic/configural processing). However, when the face is presented in the unusual upside-down orientation it is decoded into elementary features (analytic processing), so its recognition is known to be severely disrupted (Farah et al., 1998, Maurer et al., 2002). In the present study we have used the network neuroscience approach to analyze brain mechanisms of holistic and analytic face processing using the face inversion effect. Stimuli were 30 grayscale photographs (15 female and 15 male faces) from WSEFEP Database (Olszanowski et al., 2015). Faces were limited by a mask highlighting only internal features. To impair holistic processing two types of facial images were created for each photograph - an inverted image and a scrambled image. All stimuli (upright, inverted and scrambled) were presented randomly for 600 ms. Forty-five participants (33F, 12M, age range 19-24) were tested. They were asked merely to look at the image (free-viewing task). During the perception EEG brain responses were recorded with 64 electrodes placed according to the international 10-10 system with a Brain Products ActiChamp amplifier (BrainProducts, Munich, Germany). Using mathematical graph theory, we calculated measures of brain integration (graph characteristic path length) and segregation (cluster coefficient of a graph) for different EEG frequency bands. We have found that the EEG cluster coefficient in theta (4-8 Hz) range varied with the types of the presented faces ($F(1, 110)=7.63$, $p=0.01$). The cluster coefficient was lowest for the inverted faces ($M=0.56$, $SD=0.03$)

and highest for the upright faces (M=0.6, SD=0.02). The link between the holistic/analytic processes in face perception and the brain integration/segregation mechanisms is discussed.

Acknowledgements: This study was funded by Russian Scientific Fund, project 19-18-00474

Poster Session G > Face Perception: Neural mechanisms > Poster G137

Time-varying functional connectivity reveals fast, band-limited communication between amygdala and cortex during face presentation

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The ability to process faces is valuable for social interaction, aiding identity judgment and emotional expression. As such, numerous brain regions play a role in face processing. fMRI experiments have demonstrated that the amygdala responds to face stimuli, but the role of the amygdala in the face processing network remains unknown. We used magnetoencephalography (MEG) to investigate the timing and directionality of spectral activity in the amygdala in response to faces. We measured brain activity with MEG while subjects viewed a series of face and object stimuli. Subjects performed a 1-back task, pressing a button if the face or object matched the image presented on the previous trial. We collected a total of 160 trials per category (face or object). We found that the amygdala responded more strongly to faces relative to objects within the first 200 ms in the beta (20-30 Hz) and low gamma (30-50 Hz) frequency bands. In the low gamma-band, amygdala activity was phase-locked to the fusiform gyrus during the first 200 ms, with a phase-slope index suggesting communication from the amygdala to the cortex during this temporal window. Previous studies have demonstrated that faces, emotional expression, and eye gaze all evoke gamma-band amygdala activity (Sato et al, 2013; Liu et al, 2015). Our results build on these earlier studies by demonstrating the timing and directionality of functional band-limited connectivity between the amygdala and visual cortex during face processing, and suggest that computations in the amygdala immediately following stimulus onset may be communicated to cortex for further processing at later points in time.

Poster Session G > Face Perception: Neural mechanisms > Poster G138

Coarse-to-fine processing of faces throughout the ventral visual hierarchy.

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Several recurrent models of vision propose that low and high levels of the ventral visual hierarchy interact over the course of processing to build up progressively finer representations of the visual input. Previous research (Goffaux et al., 2010) suggests that high-level face-preferring regions initially process coarse information (low spatial frequencies, LSF) and later process finer details (high spatial frequencies, HSF). We conducted a block-design fMRI experiment with 18 subjects to explore whether V1 contributes to the coarse-to-fine build-up of face representations, as predicted by recurrent theories. We expected LSFs to be encoded early and rapidly, and HSFs to be encoded more slowly and progressively over the course of processing. Broadband unfamiliar face images were shown for either 50, 83, 100 or 150ms, masked by their phase-scrambled counterparts. The scrambled masks were filtered to selectively contain either LSF (< 11.5 cpi) or HSF (>11.5 cpi), targeted to selectively interfere with the processing of the LSF or HSF of the broadband faces, respectively. In early stages of processing (50ms), V1 showed a preference for LSF compared to HSF processing. Over time, responses to LSF decreased, while progressively increasing for HSF. By the later stage of processing (150ms), responses were higher for HSF than for LSF processing. Similar results were found in the right fusiform face area, agreeing with previous research (Goffaux et al., 2010). Taken together, we provide evidence for coarse-to-fine processing in both low and high levels of the visual hierarchy. Our findings shed light on the potential role of V1 in the progressive build-up of detailed representations of faces in the visual system. Next, we will explore whether low and high levels of the visual hierarchy interact over the course of processing as predicted by recurrent models of vision.

Poster Session G > Face Perception: Neural mechanisms > Poster G139

Comparing stimulus-evoked and spontaneous responses of face-selective multi-units in humans

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The face-selective response in the human occipito-temporal cortex has been extensively explored at the level of large neural populations (e.g., using functional MRI [fMRI], electroencephalography / magnetoencephalography, or intracranial local field potential), but not at the level of single or multi-units. We have recently reported a rare case of two face-selective units located in the vicinity of the Fusiform Face Area, recorded from a patient with epilepsy (Axelrod et al., 2019, Neurology). These units exhibited a robust (300% and more) modulation for a variety of facial stimuli. In addition to the stimulus-evoked response, it is well established that neurons also fire spontaneously, without any task. Notably, the degree of similarity between the magnitudes of stimulus-evoked activity and spontaneous activity is still unclear. In the present study we capitalized on a rare face-selective multi-unit recording from a human subject, to compare stimulus-evoked activity elicited by static images of faces and spontaneous activity recorded during a 6-minute continuous resting-state session. We found that generally, the magnitude of the face-selective stimulus-evoked response was much greater than the magnitude of spontaneous activity. However, this difference also depended on the duration of the time-window (i.e. a period of interest) utilized to examine the response. In particular, for time-windows of 150 ms and more, there were few spontaneous responses with comparable firing rates to those found in the face-selective evoked response. However, for shorter periods of interest (e.g. 50 ms), when comparing an equal number of windows, about 10-20% of the firing rates recorded during spontaneous activity were comparable to those recorded during the face-selective stimulus-evoked response. Overall, the present results provide a unique perspective on the relationship between stimulus-evoked and spontaneous neural activity.

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Event-related brain potentials reveal robust face identity learning after a brief real-life encounter

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Previous studies have demonstrated that pre-experimentally unfamiliar faces elicit a familiarity effect in event-related brain potentials (ERP) following a lab-based learning task, with more negative amplitudes for learnt relative to unfamiliar faces in the N250 component. However, no study has tested this effect following a brief naturalistic exposure, and the temporal dynamics of face learning in ecologically more valid conditions have not been fully explored. The present study therefore used ERPs to investigate whether robust image-independent representations could be detected after a brief real-life encounter. In Experiment 1, the participants interacted with an unfamiliar, 'to-be-learnt' person for 30 min in a face-to-face conversation, directly followed by an EEG session in which they were shown highly variable "ambient" images of the newly learnt person and an unfamiliar face. ERPs revealed more negative amplitudes for the newly learnt identity at occipito-temporal channels in a 200-300 ms time window (N250) reflecting visual recognition. In Experiment 2, the learning time was reduced to 10 min in an attempt to establish the minimum exposure that still results in robust image representations. The N250 familiarity effect was again observed, which suggests that a 10 min social encounter is sufficient for image-independent representations to be established. We conclude that the first ten minutes of a social encounter are crucial for the generation of facial representations, and that the addition of twenty extra minutes from the

same encounter does not provide a further learning benefit. At the same time, the effects found in these two experiments were small relative to those observed in previous studies investigating familiar face recognition. This suggests that the newly formed representations in the present study had not reached the same degree of image independence as those of more highly familiar faces.

Poster Session G > Face Perception: Neural mechanisms > Poster G141

Intracranial electroencephalography reveals neurodynamics underlying face perception during real-world vision in humans

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Neural correlates of true, real-world vision remain almost entirely unknown. The lack of understanding of real-world vision is particularly problematic in the context of face perception where passive viewing of static, unfamiliar, and isolated faces, briefly presented in between blank screens bears little resemblance to the richness of real-world interpersonal interactions. The real world features context, familiar faces present in relatively stable positions and active sampling of information via eye movements. To address these gaps in knowledge, we simultaneously recorded intracranial electroencephalography (ECoG), eye-tracking and videos of scenes being viewed by human subjects over hours of natural conversations with friends, family, and experimenters. These videos were annotated on a frame-by-frame basis using computer vision models, to assess when subjects were fixating faces. The fixated faces were manually labeled for identity and emotional expression classification and the face at each fixation was extracted to allow for face image reconstruction based on neural activity and, inversely, neural reconstruction based on facial information. Neural selectivity for real-world facial identity and expression classification was seen distributed across occipital, temporal, parietal and cingulate cortices and had both overlap and critical spatiotemporal differences compared to when subjects viewed faces in traditional paradigms. Accurate reconstruction of the faces of different individuals, as well as the face of an individual with different emotional expressions, was seen using fixation locked neural activity. Conversely, reconstruction of fixation locked neural activity from face stimuli was accurate for specific frequency bands and temporal periods of the neural response, suggesting a relationship between facial features and oscillatory mechanisms during real-world interactions. These findings demonstrate the role of neurodynamics in capturing fine-grained details of facial information during real-world visual perception and demonstrate that combining invasive neural recordings with real-world behavior can be used to achieve a neurocomputational understanding of natural facial perception.

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Poster Session G > Face Perception: Neural mechanisms > Poster G142

Semantic Decoding of Affective Face Signals in the Brain is Temporally Distinct

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Facial expressions are a rich information source from which observers infer the emotional states of others. Despite much understanding about the brain regions that represent facial expressions, we do not yet know how representations of these facial movements transform into judgments of emotions in the brain. We addressed this question in 5 participants who judged the emotion of individual face movements called Action Units (AUs) while we concurrently measured brain activity using magnetoencephalography (MEG). Stimuli were animations of 5 facial movements--Outer Brower Raiser (AU2), Nose Wrinkler (AU9), Lip Corner Puller (AU12), Chin Raiser (AU17), Lip Stretcher (AU20), each at 4 levels of intensity (%25 - %100). We instructed participants to rate each animation according to either its perceived valence (‘negative’, ‘neutral’ or ‘positive’) or arousal (‘low,’ ‘neutral’ or ‘high’). Tasks alternated between blocks of 40 trials (5 AUs X 4 intensity levels X 2 repetitions) and participants completed 4,000 ~ 6,000 trials in total. We averaged all ratings of each AU and intensity level per task for each participant. We show that the arousal ratings increased along AU intensity levels while valence ratings are consistent for each AU (e.g., Nose Wrinkler (AU9) as negative and Lip Corner Puller

(AU12) as positive). Then, we calculated Mutual Information (MI, permutation test) between MEG recording and task ratings. The results revealed the spatial and temporal distribution of brain activities related to the specific valence and arousal. We found that the valence and arousal evoked similar representational peaks ~270ms and ~750 ms in the temporal lobes while a special peak from parietal lobes at 387ms for valence task that differentiated between the two inferences. Our results show where (in temporal lobes and parietal lobes) and when (at ~270ms, 380ms and 750 ms post stimulus) the brain processes dynamic AUs as meaningful affective signals.

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Poster Session G > Face Perception: Neural mechanisms > Poster G143

Using EEG frequency-tagging to measure visual representations of faces

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Visual representations of faces vary greatly across individuals, and have been linked to psychopathology (Faghel-Soubeyrand et al., 2020) and recognition ability (Tardif et al., 2019). Classification image (CI) techniques such as Bubbles offer means to measure those representations, but require long and arduous testing. Frequency-tagging has been shown to effectively measure differences in the processing of visual stimuli within seconds of EEG recording, and has been applied to study face processing (Norcia et al., 2015). Here, we evaluated whether EEG frequency-tagging could be a faster and reliable alternative to CI techniques to measure individual use of information on faces. To do so, 20 participants were asked to discriminate the gender and emotion of faces in both a Bubbles paradigm in which the spatial information available was randomly sampled (1000 trials per task, ~1h), and an EEG frequency-tagging paradigm (24x70 seconds per task) in which task relevant facial features flickered at specific frequencies (e.g. left eye: 6.31 Hz, right eye: 3.52 Hz, mouth: 8.00 Hz). We found robust oscillatory signals in occipito-temporal electrodes for all frequency-tagged features, with signal-to-noise ratio reaching >16 in individual participants ($p<.0001$). This EEG frequency-tagged activity was modulated by tasks ($F(1,294)=6.23$, $p=.0131$), matching with findings from our own Bubbles group-results as well as with previous studies (e.g. Faghel-Soubeyrand et al., 2019; Blais et al., 2008), and underlining the relevance of this signal to measure representation-specific visual information. Crucially, a participant's reliance on the facial features (the average z-scores in the Bubbles' CIs within the regions of interest) was predictive of his/her EEG signal pertaining to the brain processing of those features in the frequency-tagging paradigm ($r=.27$, $p=.009$). Overall, these findings present EEG frequency-tagging not only as a mean to measure task-specific visual representations, but also as a promising method to assess individual differences in face representations.

Poster Session G > Face Perception: Neural mechanisms > Poster G144

Extensive visual training in adulthood reduces an implicit neural marker of the face inversion effect

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Face identity recognition in humans is supported by specialized neural processes whose function is substantially impaired when simply turning a face upside-down: the Face Inversion Effect (FIE) (Yin, 1969, https://doi.org/10.1037/h0027474). Inverted faces provide a strong test for whether experience in adulthood can influence face-specific processes because they contain the same visual information as upright faces for which we already have saturated experience, and inverted faces disrupt the biological constraints present at birth for preferential looking (i.e., fewer features in the bottom part than the top part of the stimulus). However, currently, little is known about the plasticity of the neural processes involved in this FIE at adulthood. Here we investigate if extensive training (2

weeks,~15 hr) in young adults discriminating a large set of unfamiliar inverted faces can reduce the FIE for a set of entirely novel faces. 28 adult observers were trained to individuate 30 inverted face identities presented under different depth-rotated views. Following training, we replicate previous behavioral reports of a significant reduction in the behavioral FIE as measured with a challenging four-alternative delayed-match-to-sample task for individual faces across depth-rotated views (Laguesse et al., 2012, https://pubmed.ncbi.nlm.nih.gov/23019119/). Most importantly, using EEG together with a validated frequency tagging approach to isolate face individuation neural responses (Rossion et al., 2020, https://onlinelibrary.wiley.com/doi/10.1111/ejn.14865), we observe a reduction in the neural FIE at the expected occipito-temporal channels. Moreover, the reduction of the neural FIE correlates with the reduction of the behavioral FIE at the individual participant level (r=0.46). The reduction in the neural FIE is not observed in a concurrently frequency tagged control signal that peaks at the more posterior medial occipital channels and reflect general visual responses. Overall, we provide novel evidence suggesting a substantial degree of plasticity in face-specific processes that are key for face identity recognition in the adult human brain.

Poster Session G > Face Perception: Neural mechanisms > Poster G145

Face-preferring areas of the ventral stream can acquire tuning for artificial face features

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We know from previous research that regions within the ventral occipito-temporal cortex (VOTC) such as the occipital and fusiform face areas show a preference for faces and face related features and are involved in their recognition. Previous work has also shown that the recognition of inner face features (e.g. eyes and mouths) is best at their expected / usual location in the visual field. However, it is still unclear if this enhanced recognition performance is caused by a learned adaptation to input statistics or if it follows an innate, face-specific template. The ongoing global pandemic with a surge of people wearing face masks gives us an exceptional chance to investigate the processing of artificial face features. If the tuning properties of face-preferring areas are shaped by input statistics, they may also learn to respond to artificial features, given sufficient exposure. I will present preliminary fMRI results showing a significant overlap of VOTC activations evoked by faces and face masks. Our data also suggest that the neural activity evoked by face masks becomes increasingly similar to that evoked by faces over several months of high exposure. Overall, these findings point towards a high degree of plasticity in face-preferring areas and support the view that its tuning properties are shaped by input statistics. We are currently collecting behavioral data to further test this hypothesis, by probing whether the feature-location contingency observed for natural facial features can be found for artificial features as well.

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Poster Session G > Face Perception: Neural mechanisms > Poster G146

Not quite human, not quite machine: face-sensitive ERP responses to human and robot faces

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There are neural mechanisms specific to face recognition in the human brain, but how perceptual and social properties of face images interact to determine the category boundary between faces and non-faces remains an interesting question. What counts as a face according to the visual system? Humans, robots, and dolls all have faces, but do all of these engage the same mechanisms for face processing? To measure the neural activity elicited by real and artificial faces relative to objects, we used event-related potentials (ERPs) to measure participants’ responses to human faces, robot faces, and non-face objects in two experiments. In each task, we measured the amplitude and latency of the P100 and N170 ERP components, both of which are known to exhibit selectivity for face images. In Experiment 1, we presented 24 participants with upright faces of real humans, robots, dolls, and computer-generated humans, and included images of clocks as a non-face control stimulus. We found that robot faces were not significantly different from either objects or human faces in terms of N170 amplitude, suggesting they were processed in a manner 'between' being object-like and face-like. By comparison, other artificial faces did not differ from human faces in terms of P100 and N170 responses. To further investigate the possibility to robot faces inhabit a liminal space between faces and non-faces, in Experiment 2, we recruited an additional 24 participants to measure their P100 and N170 responses to upright and inverted human, robot, and clock faces. Here, we found that face inversion effects on component amplitude and latency were only partially evident for robot faces, again suggesting that robot faces are a boundary case in terms of face processing. Overall, our results demonstrate that the category status of artificial faces may have a soft boundary for some classes of artificial social agents.

Face Perception: Models and metrics

Poster Session G > Face Perception: Models and metrics > Poster G147

A large-scale, naturalistic dataset of two-person social actions

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During everyday tasks like navigating a crowded store or deciding where to sit on a bus, we perceive rich details about the social interactions of others. The ability to perceive others' social interactions is a core component of human cognition, but its neural computations are only beginning to be understood. While recent work has made progress in understanding the neural mechanisms of social interaction perception with tightly controlled stimuli, continued progress requires a dataset of social and nonsocial actions that is representative of everyday life and captures variance along a range of social dimensions, e.g. valence, cooperativity, and interpersonal relationships. However, using naturalistic stimuli to investigate social interaction perception presents significant challenges. First, the number of people in a given video is highly predictive of the presence of a social interaction–a video of one person likely shows a nonsocial action, while a video of three or more people likely shows a social interaction. Further, existing datasets of social actions are not representative of everyday actions. They dramatically oversample sporting activities, for instance. We addressed this challenge by curating a dataset of two-person social and nonsocial actions from the Moments in Time dataset. Our videos were selected from common action categories based on the American Time Use Survey. We also balanced our dataset on visual features such as whether the action occurred indoors or outdoors. Finally, we selected our final set of videos so that sociality was not predictable by early layers of a deep convolutional neural network. This dataset will be an important tool in benchmarking human social perception against computer vision models and can pave the way for the same progress that has been achieved in object and scene perception.

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Poster Session G > Face Perception: Models and metrics > Poster G148

Recall of faces quantified through an avatar creation interface

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A variety of methods have been used to study visual memory for images including recall tasks, recognition tasks, verbal description, and recently, drawing recall tasks. However, when it comes to recollection of faces, studies have largely failed to capture the precise details during free recall that allow for quantitative analysis. Here, we propose a new method utilizing an avatar creation tool to provide a numerical representation of face recollection. The interface contains a 3D character model, and sliders that range from -1 to 1 for each facial feature. Changes made to features such as nose width or prominence of laugh lines are updated in real-time, so participants can understand the effects of each slider on their representation of a face. Participants were first shown sample human faces that were constructed in the face tool for a period of time (20 seconds) and told to memorize as much as they could. After the face image was presented, they were then shown the character creation interface with instructions to recreate the face as best they could from memory. After this memory task, a perceptual task was conducted where participants had to recreate the faces again, this time with the image available as a reference. We identified key differences between face recall and perception, along with perception and the ground truth in participants' abilities to reconstruct faces. Specifically, face

reconstruction was improved when using a reference as opposed to relying on memory, demonstrating that this interface can be an effective method to capture representations of faces in perception and memory. Overall, the use of this interface allows for a new method to study the recollection of faces with precise quantification of specific features.

Poster Session G > Face Perception: Models and metrics > Poster G149

Psychophysical Scaling of Dynamic Episode-based Affective Database: A Paired-Comparison Approach

View Poster | Play Video | Visit me in Gather.Town Egret Room on Tuesday 8:00 am - 10:00 am EDT

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Vision and audition are the two primary modalities along which people can express emotional experiences. During the past two years, we have constructed an affective database where brief episodes of emotional exchange, which to a large extent emulates the real-life scenarios of emotional exchange, are created. Here we aim to create a psychophysical scale so that sample of affective episodes selected from the database can provide a precise, quantitative reference when using them for future research. Specifically, we adopted Thurstone's paired-comparison method where pairs of selected videos were compared to derive their psychophysical scaling values. Thirty-eight participants were recruited. Ten short videos with differential intensity conveying emotional expressions of six categories (i.e., happiness, sadness, anger, surprise, disgust, and fear) were paired randomly in a sequential presentation on each trial. Participants had to decide which of the pair expressed a stronger emotion of a given category. A total of 270 trials were administered. The trials were blocked according to emotional category, and the order of category was randomly administered. The results showed that the mean scaled value varied from 0.57 for videos depicting sadness to 1.97 for those depicting surprise, indicating that the range of affective scaling was somewhat constrained. Moreover, we found that the scaled values were highly correlated with previous measurements based on ratings of emotional intensity from another large group of participants for emotional expressions of happiness, anger, surprise and disgust. Furthermore, scale values for anger, surprise, and disgust were significantly, though negatively, correlated with their entropy measures. Taken together, the overall dynamic affective database can be a useful source of stimuli for investigating emotional processing and integration across two modalities, and the psychological scaling of the database can further offer precise quantitative measurements and references that may be required by specific research.

Poster Session G > Face Perception: Models and metrics > Poster G150

Facial similarity judgements are well predicted by image-computable DNNs and a statistical face distribution model

View Poster | Play Video | Visit me in Gather.Town Egret Room on Tuesday 8:00 am - 10:00 am EDT

Kamila M. Jozwik*[1], Jonathan O'Keeffe*[2], Katherine R. Storrs*[3], Nikolaus Kriegeskorte[4]; [1]University of Cambridge, [2]Cognition and Brain Sciences Unit, [3]Justus Liebig University, [4]Columbia University *Equal contribution

Despite the importance of face perception in human and computer vision, no quantitative model of perceived facial similarity exists. We designed a novel behavioural task to efficiently collect similarity and same/different identity judgements, and used it to test diverse candidate models. We rendered two sets of 232 pairs of realistic faces from the Basel Face Model (BFM), a generative statistical model based on principal components analysis of 3D face scans. The two sets had identical relative geometries in BFM but different face exemplars. Participants (N=26) arranged face pairs on a large touch-screen according to how similar they appeared, relative to anchoring pairs at the top and bottom of the screen and to other adjusted pairs. Participants also placed a horizontal bar on each trial indicating the threshold between pairs that appeared to depict "the same person" vs different individuals. We compared perceived dissimilarities with diverse distance metrics derived from the BFM, image properties, or deep neural networks (DNNs) trained either on objects or faces. A face-recognition trained DNN (especially late intermediate layers) predicted human judgements best and explained unique variance over simpler image-based models. However, distances within the BFM performed almost as well, despite capturing only the distance between faces in principal-components space, with no image information. The performance was improved by taking a sigmoidal function of BFM distances. Judgements were similar for both

stimulus sets (different face exemplars but same relative geometries). Faces with clearly perceptible differences were tolerated as belonging to the same identity, and the identity threshold aligned approximately with the statistically expected distance between random individuals in the BFM. Human facial similarity judgements appear tuned to the distribution of facial features, and can be well predicted by both statistical face models and image-computable DNNs.

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Poster Session G > Face Perception: Models and metrics > Poster G151

Causal inference in face identification, matching, and verification

View Poster | Visit me in Gather.Town Egret Room on Tuesday 8:00 am - 10:00 am EDT

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Face identification, matching, and verification are fundamental tasks in daily life and are important in social, forensic, and clinical settings. Accurate performance of these tasks requires robust representations of identity that are invariant to environmental changes in lighting, viewpoint, size, etc., much like in the general case of object detection and recognition. Feature detection and comparison are important to accomplishing these tasks and are well-studied both behaviorally and neuroscientifically. However, faces themselves also change in ways that are material to identity and appearance — e.g., by wrinkling, tanning, microblading, shaving, scarring, growing out a beard, losing weight, and getting a face lift. Accurate performance of face-based tasks therefore requires not only the available face features and context, but also a robust model of face-specific causal forces. Here, we cast the tasks of face identification, matching, and verification as problems of casual inference. We model identity as a probability distribution over a metric face space and identity-based tasks as Bayesian model comparison across intuitive causal psychological models of how faces change and are sampled in identity-based tasks. The problem of face matching, for example, can be expressed as comparison between two models of how the face images were generated: (1) they were sampled from two distinct identity distributions or (2) one was sampled from an identity distribution and the other is a transformation of that sample via one or more causal mechanisms known to the observer. Through computational modeling and demonstrations, we show that observers have a rich understanding of the causal mechanisms that affect identity and appearance and can use that knowledge to make accurate inferences unattainable by approaches that rely only on feature detection and comparison.

Poster Session G > Face Perception: Models and metrics > Poster G152

Deep networks trained to recognize facial expressions predict ventral face-selective ECoG responses as well as networks trained to recognize identity

View Poster | Play Video | Visit me in Gather.Town Egret Room on Tuesday 8:00 am - 10:00 am EDT

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Faces are a rich source of information about people’s identity and their facial expressions. Recognition of identity and expression have been traditionally thought to be performed by separate neural mechanisms. However, recent neuroimaging studies suggest that recognition of identity and expressions may not be as disjointed as originally thought: valence can be decoded from patterns of response in the FFA (Skerry & Saxe 2014), a brain region previously implicated in identity recognition. If ventral temporal face-selective regions are specialized for the recognition of identity, we would expect deep networks trained to recognize identity to provide a better model of neural responses in these regions as compared to networks trained to recognize facial expressions. In this study, we used electrocorticography (ECoG) to test this prediction, comparing the similarity between neural representations and representations from deep networks trained to recognize either identity or expressions. Patients were shown face images from the Karolinska Directed Emotional Faces database (Lundqvist et al., 1998) while intracranial recordings from ventral temporal brain regions were collected. Using temporal representational similarity analysis for each electrode over sliding temporal windows, we compared representational dissimilarity matrices (RDMs) obtained from the ECoG data to RDMs obtained from one model trained on expression recognition and one model trained on identity recognition. Similarity between

RDMs from different layers of the DNNs and the RDMs obtained from ECoG data at different time windows was also evaluated. RDMs from networks trained to recognize expression and those trained to recognize identity were equally able to explain ventral temporal regions when presented with face stimuli. These results provide further support for the presence of both identity and expression information within common brain regions and suggest that ventral temporal regions may not be exclusively optimized for identity recognition.

Poster Session G > Face Perception: Models and metrics > Poster G153

Exploring perceived face similarity and its relation to image-based spaces: an effect of familiarity

View Poster | Visit me in Gather.Town Egret Room on Tuesday 8:00 am - 10:00 am EDT

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One challenge in exploring the internal representation of faces is the lack of controlled stimuli changes. Researchers are often limited to verbalizable changes in the creation of a dataset. An alternative approach to verbalization for interpretability is finding image-based measures that allow us to quantify image manipulation. In this study, we explore whether PCA could be used to create controlled changes to a face by testing the effect of these changes on human perceived similarity and on computational differences in Gabor, Pixel and DNN spaces. In Experiment 1, the effect of single dimensional (PCA) colour or shape changes in unfamiliar faces was explored. We found that perceived similarity and the three image-based spaces are linearly related, almost perfectly in the case of the DNN, with a correlation of 0.94. This provides a controlled way to alter the appearance of a face. In experiment 2, the effect of familiarity on the perception of multidimensional changes was explored. Our findings show that there is a positive relationship between the number of components changed and both the perceived similarity and the same three image-based spaces used in experiment 1. We found that familiar faces are rated more similar overall than unfamiliar faces. That is, a change to a familiar face is perceived as making less difference than the exact same change to an unfamiliar face. The ability to quantify, and thus control, these changes is a powerful tool in exploring the factors that mediate a change in perceived identity.

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Poster Session G > Face Perception: Models and metrics > Poster G154

Using task-optimized neural networks to understand how experience might shape human face perception

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We perceive and recognize faces quickly and seemingly effortlessly. How does this remarkable ability develop and what is the role of experience? Here we addressed these long-standing questions by leveraging recent successes in deep convolutional neural networks (CNNs) as models for human visual recognition. Specifically, we asked whether training on generic object recognition is sufficient for CNNs to capture human face behavior, or whether face-specific training is required. To measure human face perception, subjects (n=14) performed a similarity arrangement task on 80 different face images (five images of 16 different identities). Using representational similarity analysis, we compared the behavioral representational dissimilarity matrices (RDMs) to RDMs obtained from different layers of CNNs (i.e., VGG16) trained on either object (Object CNN) or face identity (Face CNN) categorization. Importantly, the face identities used as stimuli were not included in the training, and thus “unfamiliar” to both the Face and Object CNN. We found that the human face behavior RDM was more similar to layer-specific RDMs of the Face CNN (max. Spearman’s r=.42, reaching the noise ceiling) compared to the Object CNN (max. Spearman’s r=.21). Moreover, late layers in the Face CNN matched human face behavior better than early layers. These results show that face-trained CNNs capture human face behavior better than object-trained CNNs. Further, these results suggest that humanlike face perception abilities do not automatically arise from generic visual experience with objects. Instead, face-specific experience during development may shape and fine-tune human face perception.

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Poster Session G > Face Perception: Models and metrics > Poster G155

What type of experience is needed to generate a human-like view-invariant representation of face identity? Evidence from Deep Convolutional Neural Networks

View Poster | Play Video | Visit me in Gather.Town Egret Room on Tuesday 8:00 am - 10:00 am EDT

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Face recognition depends on the generation of a view-invariant representation of face identity. We have recently discovered a subset of view-invariant facial features that humans use for face identification. But what type of experience is needed in order to generate this face representation? This question is hard to answer in humans as we have no access to the type of experience humans have with faces during development. In previous studies, we discovered that face-trained deep convolutional neural networks (DCNNs) are sensitive to the same subset of facial features humans use for face identification. This sensitivity emerges at high layers of the network, where a view-invariant representation of face identity is generated. These models enable us to ask what type of experience is required to achieve this human-like, view-invariant face representation. To that end, we systematically trained a DCNN with different number of identities and different images per identity. We found that the number of training images that is required for the generation of sensitivity to human-like critical features corresponds with the generation of a view-invariant face representation. Furthermore, we found a tradeoff between the number of identities and the number of images per identity that are required to generate a view-invariant representation such that training with 10 identities requires 300 images per identity, whereas training with 1000 identities requires only 10 images per identity. These findings suggest that sensitivity to human-like view-invariant facial features that define the identity of the face can be achieved with a relatively small training set. These findings may shed light on the initial stages of development of the human face recognition system suggesting that infants who are exposed to a relatively small number of identities during their first year of life can already extract identity-relevant facial information.

Poster Session G > Face Perception: Models and metrics > Poster G156

Investigating the role of orientation information in face processing within a spiking neural network

View Poster | Visit me in Gather.Town Egret Room on Tuesday 8:00 am - 10:00 am EDT

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Specialised face processing in fusiform-face-area relies on horizontal orientations (Goffaux et al. 2016). We developed a neural-network to investigate the roles of different levels of the visual system. We trained a spiking-neural-network with face images (54x54 pixels), using a spike-time-dependent-plasticity (STDP) learning rule whereby synapses receiving spikes before/after the cell fires are strengthened/weakened (Masquelier and Thorpe, 2007). This network type closely matches V1 receptive fields (RF) (Cottereau et al. 2019). The network had a convolutional LGN layer consisting of ON and OFF cells and a convolutional V1 layer consisting of 4 Gabor orientation filters (0/90/45/135 degrees, with ~2 spatial frequency cycles-per-RF). Each V1 cell type (0/90/45/135) had synaptic connections to one of LGN cell type (ON/OFF). Thus there were 8 channels in V1. Each cell in the final layer (N=20) had synaptic connections to all V1 cells (thus a total of 2x4x54x54=23328 synapses). After training, we inspected the synaptic weights (learned though STDP) connecting the V1 layer to the final layer. The weights learned for horizontal V1 channels were highest around the eyes, eyebrows and mouth - highly important for face identification, whereas weights for the vertical channels were highest for

the sides of the head/ears and nose. Next we measured the local similarity of the weights at each pixel location, separately for horizontal and vertical channels. There was significantly increased similarity around the eyes in the horizontal compared to vertical channel. This may mean that a small and specific configuration of horizontal orientation filters are useful in representing this face region. These results replicate previous research and suggest that specific facial features may drive the reliance on horizontal orientations. Moreover, different RFs converged on a similar configuration of horizontal orientations to represent the eyes - possibly indicating a smaller space of possibilities for representing certain facial features.

Poster Session H

Eye Movements: Neural mechanisms

Using electrooculography to track closed-eye movements.

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Tuesday 3:00 pm - 5:00 pm EDT

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There are several areas in the study of visual cognition—including memory, imagery, and human-machine interaction—where researchers are interested in how the eyes move behind closed eyelids. However, reliably and affordably measuring closed-eye movements has proven elusive. Electrooculography (EOG) offers a low-cost solution to monitoring closed-eye gaze position, but it is not without its challenges. To determine the direction and amplitude of eye movements, the electrical potentials measured by EOG somehow must be calibrated with the angular displacement of the eye. EOG is also susceptible to noise arising from various sources, such as electromyographic activity and electrode impedance. Here we describe a method for estimating a corrected EOG signal by calibrating it with an industry-standard, pupil-corneal reflection (PCR) eye tracker. First, data were collected while simultaneously using both eye-tracking techniques as participants performed a simple horizontal saccade task with their eyes open under conditions of normal illumination and complete darkness. The EOG signal, when using only a standard calibration procedure, was less precise than that of PCR and tended to overestimate saccadic amplitude. We applied robust regression methods to the EOG and PCR data recorded in normal illumination to estimate a calibration factor to adjust the EOG signal acquired in darkness. This adjustment yielded an EOG-based measure of saccade end-points that was more comparable—in both accuracy and precision—to that obtained from the PCR data. Having validated this calibration procedure, we applied it to compute an adjusted EOG measure of saccadic amplitude in another condition where participants' eyes were closed. This adjustment likely improved our measurement of how accurately participants were able to execute closed-eye movements to remembered target locations. We propose that the refinement and application of this methodology can advance research under conditions where researchers would like to measure the kinematics of closed-eye movements.

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Discriminable human gaze patterns for solid objects versus 2-D and 3-D pictures of those objects

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In everyday life, humans rely heavily on vision to identify objects and to guide the hands towards them to support goal-directed actions. Recent research has begun to question the ecological validity of using impoverished stimuli, such as two-dimensional (2-D) computerized images, as proxies for real-world solid objects to study perception and action. Real objects differ from 2-D pictures in many aspects, including the availability of binocular depth cues and the fact that they are tangible, actionable solids. Here, we measured gaze patterns towards everyday kitchen and garage tools by human adults during an object categorization task and an object grasping task. The stimuli were presented to observers as real-world solids, 2-D computerized images, or three-dimensional (3-D) stereoscopic images. The 2-D and 3-D images were matched closely to their real-world counterparts for retinal size, viewpoint and illumination, and event timing was computer-controlled on all trials. We used linear discriminant analysis (LDA) to determine whether eye movements to stimuli in each display format could be reliably discriminated based on the evolution of gaze position throughout the trials. Gaze patterns towards stimuli in the three display formats were highly discriminable from each other, both during

the visuomotor grasping task and the visual categorization task, particularly in the first several hundred milliseconds of each trial. Gaze patterns towards 2-D and 3-D images of objects were more similar to each other than to those towards solid objects. Specifically, participants' early gaze tended to linger towards the handles of real tools more so than on those of their 2-D and 3-D picture counterparts. These results illustrate that even very early behavioral responses towards objects depend critically on the format in which the stimuli are presented. Our findings underscore the importance of using ecologically valid stimuli to understand real-world vision and action.

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Poster Session H > Eye Movements: Neural mechanisms > Poster H3

Torsional eye movements while viewing an illusory tilted scene

View Poster | Visit me in Gather.Town Osprey Room on Tuesday 3:00 pm - 5:00 pm EDT

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Static images produce torsional eye movements known as optostatic torsion, which may be greater when adding spatial clues. In this study we investigated static tilted scenes, and images with an illusory tilt. Illusory images were of the Café Wall type. Eye movements were recorded in real-time, participants gazing straight ahead. Two participants sat with torso and head upright, supported by chinrest and forehead rest. After 20 seconds of darkness, stimuli were projected (4096 x 2160, 60Hz) at 90 cm. Tilted scenes were of the Lincoln Memorial, diameter 51° visual angle (86 cm). Illusory stimuli consisted of a black square 19.7 cm diagonal (12.4° visual angle) surrounded by 40 rows of black and white alternating tiles, 20 tiles/row, 51° visual angle. Thin gray lines separated the tile rows, as in the Café Wall illusion, producing a perception of tilt. Clockwise (CW) and counterclockwise (CCW) stimuli appeared for 60s, 4 times each, ±30° in alternating sequence. Illusory stimuli were always upright, configured to appear tilted CW or CCW. Eye movements were recorded at 100Hz by infrared camera (FLIR Grasshopper3 USB3), located 24 cm in front of the participant. Torsional eye position was calculated by tracking the iris pattern. Optostatic effects were replicated using tilted scenes. Average ocular torsion was -1.2 ± 0.02° for CCW stimuli, and 0.49 ± 0.48° for CW stimuli. Illusory stimuli did not produce appreciable differences in ocular torsion, comparing CW and CCW configurations. Average ocular torsion was -0.28 ± 0.16° for CCW stimuli, and 0.03 ± 0.13° for CW stimuli. Optostatic torsion is replicable in different experimental setups with various methods of eye tracking. Under comparable conditions, static illusory images did not produce comparable amounts of torsion. Future investigations should probe additional parameters of stimuli that produce illusory tilt phenomena.

Poster Session H > Eye Movements: Neural mechanisms > Poster H5

A Model of the Post-saccadic Dynamics of Visual Sensitivity

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Humans explore visual scenes by continually alternating rapid gaze shifts (saccades) with slow eye movements (ocular drifts). Recent work has shown that, on the retina, this oculomotor alternation yields a luminance flow with power equalized within a bandwidth that oscillates with the saccade/drift cycle (Mostofi et al, Current Biology 2020). Here we use neural modeling to investigate the possible impact of this visual input signal on retinal activity and perception. The responses of retinal ganglion cells (magno- and parvo-cellular, ON and OFF) were modeled at various eccentricities via spatiotemporal filters based on neurophysiological data. Neurons were assumed to be insensitive to purely stationary stimuli (0 Hz), hence primarily driven by luminance fluctuations elicited by eye movements. The model was exposed to luminance flows experienced by human subjects detecting a grating annulus (spatial frequency at 2 or 10 cpd; eccentricity of 0, 4 or 8°; and width of 1.5°) embedded in a natural noise field. The stimulus was displayed with variable post-saccadic exposure (50, 150, or 500 ms) contingent with the onset of a 6° saccade. Post-saccadic neural responses were cumulated by a standard decision-making stage to report the presence/absence of the grating. The model closely replicates human visual dynamics at all considered eccentricities. Responses to the luminance changes induced by eye movements cause visual sensitivity to low spatial frequency to saturate immediately after the saccade and sensitivity to high spatial frequency to continue increasing during post-saccadic drifts. These findings support the proposal that eye movements are major contributors to visual sensitivity. They indicate that quantitative models of retinal responses are sufficient for predicting the dynamics of contrast sensitivity across the visual field during natural viewing.

Acknowledgements: This work was supported by Facebook Reality Labs and by National Institutes of Health grants EY018363 (MR) and EY029565 (JI).

Poster Session H > Eye Movements: Neural mechanisms > Poster H6

Temporal dynamics of peri-microsaccadic perceptual modulations in the foveola

View Poster | Visit me in Gather.Town Osprey Room on Tuesday 3:00 pm - 5:00 pm EDT

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Before the eyes begin to move, vision is briefly enhanced at the saccade goal, followed by a plummet in sensitivity as the eyes relocate the center of gaze. Recent work showed that vision is also enhanced foveally in a similar fashion before the onset of microsaccades. Here we examine these selective modulations of foveal vision at a finer temporal grain before, during and after the onset of microsaccades. Fixational eye movements were monitored with a high-resolution DPI eye-tracker while subjects performed a high-acuity discrimination task. Human observers (N=4) shifted their gaze with microsaccades to one of two foveal locations (20’ away) based on a preceding a saccade cue. High-acuity stimuli (7’x3 titled bars’) were then briefly presented at varying times relative to microsaccade onset. A response cue appeared after microsaccade execution and subjects reported the orientation of the stimuli previously presented at the location indicated by this cue. Our findings show that stimuli presented at the microsaccade goal were perceptually enhanced. The extent of this enhancement was such that discrimination performance at this location equated performance when stimuli were presented at the preferred locus of fixation (82%±0.1% vs 85%±0.1%, p=0.75). On the other hand, sensitivity at isoeccentric locations opposite to the microsaccade goal, was impaired compared to baseline (61%±0.1% vs 78%±0.1%, p<0.01). This modulation started ~150ms prior to the microsaccade onset. High acuity vision was severely impaired if stimuli were presented when the eyes were in flight. However, within 50 ms from microsaccade landing perception rapidly recovered back to baseline. These findings show that foveal vision drastically changes around the time of microsaccades, and that pre-microsaccadic modulation of foveal vision equates fine spatial vision at the microsaccade goal to that at the preferred locus of fixation, where acuity is highest.

Acknowledgements: NIH R01 EY029788-01 to MP, NSF Award 1449828 to ZS

Poster Session H > Eye Movements: Neural mechanisms > Poster H7

Alterations in oculomotor behavior in healthy aging and mild cognitive impairment

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Age-related changes in saccade behavior on short timescales (a few seconds) is often ascribed to changes in sensorimotor processing, working memory, or executive functioning. Visual exploration is additionally guided, at long timescales (minutes to hours), by memory representations supported by the hippocampal and broader medial temporal lobe system. Here, we examined whether age-related and neurodegenerative changes to the memory system impact more immediate saccade behavior by comparing the performance of younger adults (YA), healthy older adults (HOA), and older adults diagnosed with amnestic mild cognitive impairment (aMCI). 27 YA (18-35 years), 34 HOA (60-86 years) and 9 aMCI (46-84 years) performed a set of saccade tasks that systematically manipulated memory demands and the complexity of saccadic behaviour. A subset of tasks involved single saccades directed to a target 1) immediately (visually-guided task), 2) after a variable delay 500-1500 ms (gap), and 3) to a remembered location after a variable delay 300-3000 ms (memory-guided task). In another set of memory-guided tasks, participants directed saccades to two remembered targets in sequential and reverse order after a variable delay (double-step forward and backward). Using a multivariate partial least squares analysis, HOA and MCI groups were shown to have longer initial saccade latencies than YA in all but the visually-guided task. HOA and MCI initial saccade latencies did not differ significantly. Second saccade latencies in the double-step forward task were shorter for HOA than YA but longer for MCI as compared to the other two groups. Spatial errors did not differ across groups, suggesting that the differences in latencies were not due to differences in speed-accuracy tradeoffs across groups. Our results confirm previous findings of the impact of age-related changes in sensorimotor processing on saccade behavior. Our findings suggest that functional changes in the medial temporal lobe may affect oculomotor guidance on short timescales.

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Poster Session H > Eye Movements: Neural mechanisms > Poster H8

Eye movement deficits in Parkinson's patients are compensated during go/no-go manual interceptions

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Parkinson's disease (PD) is a neurodegenerative disease that causes motor impairments, such as tremor or slowing. Here we investigate whether these deficits extend to goal-directed eye and hand movements and sensorimotor decisions. Sixteen early stage PD patients with mild to moderate symptoms and 18 age-matched healthy controls performed baseline smooth pursuit tracking, pro- and anti-saccades (Munoz & Everling, 2004), and go/no-go manual interceptions. During the go/no-go interception task observers had to predict whether a moving target would pass through (go required) or miss (no-go required) a designated strike box. Only the initial launch (300 or 500 ms) of the target was shown, requiring observers to extrapolate the target trajectory to decide whether and when to intercept. Eye and hand movements were recorded with a video-based eye and magnetic hand tracker. Patients made more catch-up saccades than controls during baseline pursuit, showed systematic eye movement impairments during visually guided (pro-) saccades, and made a higher number of corrective saccades (changes of mind) during the anti-saccade task. Yet, eye movements were unimpaired compared to the control group during the track-intercept task and patients exhibited similar interception timing and go/no-go decision accuracy. Interestingly, PD patients initiated hand movements earlier than controls, indicating the ability to compensate for motor slowing by adapting eye and hand movement timing. These results suggest that early stage PD patients show most impairments during visually guided pursuit and saccades, but seem to preserve function in higher-level tasks.

Poster Session H > Eye Movements: Neural mechanisms > Poster H9

Objective Dynamic Visual Acuity Assessment Method Based on Steady-State Visual Evoked Potentials with Smooth-Pursuit Eye Movements Recording

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Dynamic visual acuity (DVA) is a measurement of the ability to discriminate critical details of relative moving objects. It is regarded as a superior observation index that can reflect the comprehensive functional state of a vision system. However, there is still not a gold criterion for DVA assessment in the clinical test. Recently, steady-state visual evoked potential (SSVEP) is proved as an objective, quantitative and sensitive method of evaluating objective visual acuity. By recording and analyzing SSVEP signals and eye movements, a new approach to assess DVA levels can also be provided. In this study, we designed a special paradigm to induce EEG and eye movement signals simultaneously. A checkerboard flips in the background at 7.5 Hz, while the visible part of a mask makes a circular motion, which is stable in stimulation and convenient for programming. The spatial frequencies of checkerboard optotypes were designed into ten levels, corresponding to the minimum angle of resolution of 1′ to 10′. The visible part was 10° to the subjects, and its velocity was set at two speeds (20°/s and 40°/s). The empirical mode decomposition (EMD), canonical correlation analysis (CCA), and some statistical methods were used in signal processing. The frequency feature of the SSVEP signals was calculated to reflect DVA levels. The standard error (SE) of eye movements was used as the test's reliability index to prevent ineffective eye tracking movements. The result of the proposed objective method was compared with a

traditional subjective method, e.g., DinVA 3.0. The objective and subjective visual acuity of fifteen healthy adults were tested at both speeds. It was confirmed that their results were correlated significantly. Our study proved that SSVEP is an objective and quantitative method to measure dynamic visual acuity. The combination of eye movements and EEG signals is feasible and shows excellent potential.

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Smooth Pursuit Stabilizes Objects in Perceptual and not Retinal Coordinates

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The function of smooth pursuit eye movements is classically thought to be to stabilize the image of a moving object on the retina. Here we ask whether the stabilizing operation carried out by smooth pursuit operates over positions on the retina or over perceived positions. Participants smoothly pursued the invisible midpoint (Steinbach, 1976) between two Gabor patches aligned in the vertical plane and moving on parallel, oblique paths. On some trials, the Gabors' internal texture drifted orthogonally to their envelopes' motion direction. These moving Gabors with internal drift, also known as the double-drift stimulus, induce a large offset of the perceived from the physical position of up to several degrees. The results showed that smooth pursuit eye movements follow the illusory trajectory rather than the physical. Thus, smooth pursuit operates on perceptual rather than retinal coordinates.

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Poster Session H > Eye Movements: Neural mechanisms > Poster H11

Post-saccadic dynamics of visual sensitivity across the visual field

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Humans continually move their eyes, alternating saccades with an otherwise incessant jitter known as ocular drift. Recent work has shown that this stereotypical alternation cyclically modulates the luminance flow impinging onto retinal receptors, yielding temporal signals that enhance high spatial frequency during eye drifts and enhance low spatial frequencies with saccades. Psychophysical experiments with foveal stimuli have provided support to these ideas. Here we examine whether similar principles apply outside the fovea, where photoreceptors are less dense. Following a saccade (6.6o amplitude), human observers (N=9) were asked to detect a circular grating (the stimulus; either 2 or 10 cycles/deg) embedded in a naturalistic noise field. Eye movements were continuously monitored at high resolution by means of Dual-Purkinje-Image eye-trackers, and the stimulus presented as soon as the saccade started (average delay: 11 ms) in 50% of the trials. Contrast sensitivity functions were measured at three eccentricities (0, 4 and 8) and with three durations of post-saccadic exposure (50, 150, or 500 ms). Only traces in which the saccade was followed by uninterrupted drifts were considered. Very similar dynamics were found at all considered eccentricities. Visual sensitivity to 2 cycles/deg was immediately high 50 ms following the saccade and did not improve with further post-saccadic exposure. In this low frequency range, sensitivity was surprising uniform across the visual field. In contrast, sensitivity to 10 cycles/deg continued to increase during post-saccadic fixation. As expected in this high frequency range, sensitivity decreased with increasing eccentricity, but the rate of improvement with post-saccadic exposure was similar across eccentricities. Most of the improvement occurred between 50 ms and 150 ms, but sensitivity continued to increase past 150 ms. These results suggest that the luminance modulations from the natural saccade-drift alternation contribute to a coarse-to-fine processing dynamics throughout the visual field.

Acknowledgements: This work was supported by National Institutes of Health grant EY018363 and Facebook Reality Labs.

Poster Session H > Eye Movements: Neural mechanisms > Poster H12

A natural look at scanpath theory: The way we move our head and eyes predicts scene recognition

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It has long been thought that visual perception is represented in sensorimotor processes that unfold over time. One prominent theory states that our memory for a scene contains both the scene's content and the motor commands used to explore the scene (i.e., eye movements). Scanpath theory (Noton & Stark, 1971) has long been contested, with studies providing evidence both for and against it. That past work, however, did not include the fact that visual perception is embodied within an active system of effectors; namely, that people normally move their head as well as their eyes when exploring visible space. The present work tested scanpath theory in fully immersive 360 degree scenes leaving individuals free to move their heads and well as their eyes while they explored scenes for a subsequent memory test. During both encoding and recognition, we recorded their head and eye movements using a virtual reality headset equipped with eye and head tracking. Relevant to scanpath theory, as well as to embodied conceptualizations of perception and memory, our results show that repeating certain head and eye movement patterns made during encoding renders those scenes more likely to be recognized.

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Features derived from a deep neural network distinguish visual cues used by CCTV experts versus novices

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When viewing actions, we not only recognize patterns of body movements, but we also "see" the intentions and social relations of people. However, there are individual differences in the ability of inferring intentions from action observations. Experienced forensic examiners, Closed Circuit Television (CCTV) operators, show superior performance to novices in predicting and identifying hostile intentions in complex scenes. However, it remains unknown what visual features CCTV operators actively attend to when viewing surveillance footages, and whether attended features differ between experts and novices. In this study, we analyzed visual contents in image patches centered on the gaze fixations of CCTV operators and of novices when they viewed the same surveillance footage of activity preceding harmful interactions and control conditions. First, a visual saliency model was used to examine the impact of salient image features (e.g., luminance, color, motion) on guiding gaze fixations in viewing dynamic scenes. We did not find a group difference between experts and novices in terms of visual saliency of attended stimuli. We then employed a deep convolutional neural network (DCNN) model to extract DCNN features from the penultimate layer of the network. Through machine learning classifiers, DCNN features from the gaze-centered input can distinguish experts from novices, specifically for surveillance videos that precede harmful interactions (e.g., fighting). DCNN features also showed greater inter-subject correlations among CCTV operators than for novices. The results suggest that experts such as CCTV operators are more efficient in attending to object-relevant information that likely is associated with social context and relationships between agents. Such differences in actively attending to high-level visual information enable the experts to better predict harmful intentions in human activities.

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Poster Session H > Eye Movements: Neural mechanisms > Poster H14

Pathologist pupil dilation reflects difficulty in diagnosing digital breast tissue biopsies

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Digital whole slide imaging allows pathologists to view biopsy slides on a computer screen instead of under a traditional microscope. Digital viewing facilitates real-time monitoring of search behavior and pupil diameter during the diagnostic process. In particular, eye-tracking could provide a basis for objective evaluation of clinical competence during training or automated tools that alert pathologists to conditions that may result in diagnostic errors. Prior research has shown that pupil diameter is sensitive to cognitive load, arousal, and switches between exploration and exploitation of the environment. Different categories of lesions in breast biopsies, from benign to cancerous, pose different levels of challenge to pathologists as indicated by elevated diagnostic disagreement for precancer and early stage cancer. If pupil diameter was sensitive to perceived difficulty in diagnosing biopsies, perhaps eye-tracking could be used to identify biopsies that may benefit from a second opinion in an effort to reduce diagnostic error. We measured baseline-corrected (phasic) and raw pupil diameter (tonic) in 89 pathologists who each viewed and diagnosed 14 breast biopsy cases that cover the diagnostic spectrum. Pupil data were extracted from the beginning of each trial. After removing 106 trials with poor eye-tracking quality, 1,140 trials remained. We used multiple linear regression with robust standard error estimates to account for dependent observations within pathologists. We discovered a positive association between phasic dilation and subject-centered difficulty, on the one hand, and between tonic dilation and untransformed difficulty ratings on the other. When controlling for biopsy ID, only the tonic-difficulty relationship persisted. Results suggest that tonic dilation may indicate overall arousal differences between pathologists and could signal a need for additional training and experience. Phasic dilation is sensitive to intrinsic characteristics of biopsies that tend to elicit higher difficulty ratings and could prompt second opinions for difficult cases.

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Poster Session H > Eye Movements: Neural mechanisms > Poster H15

PRL location consistency across tasks and participants: a simulated scotoma study

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After loss of central vision due to retinal pathologies such as Macular Degeneration (MD), patients often adopt compensatory strategies including developing a "preferred retinal locus" (PRL) to replace the fovea in tasks involving fixation. A key question is whether patients develop stable, multi-purpose PRLs or whether they adapt their oculomotor strategies to the demands of the task. While the majority of MD patients spontaneously develop a PRL, clinical evidence suggests that patients may develop multiple PRLs or switch them according to the task at hand. To understand this, we examined a controlled model of central vision loss in normally seeing individuals and tested whether they used the same or different PRL across tasks after training. Nineteen healthy participants were trained for 10 sessions on a contrast detection task in conditions of simulated central vision loss via gaze-contingent display. Before and after training, their peripheral looking strategies were evaluated during transfer tasks measuring visual acuity, reading abilities and visual search. To quantify strategies in these disparate, naturalistic tasks, we created polar plots indicating the amount of task-relevant information for each fixation in each task and compared these within and across individuals. Results showed that some participants used consistent looking strategies across tasks whereas other participants' peripheral viewing strategies differed across tasks. These results represent one of the first examinations of the extent to which peripheral viewing strategies are consistent or not within cases of simulated vision loss across tasks and suggest that individual differences in peripheral looking strategies that develop in simulated central vision loss may model those developed in pathological vision loss.

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Saccades during visual search: adaptations in the presence of a binocular scotoma

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When macular degeneration affects the foveae bilaterally, it results in a binocular scotoma that compromises both high-acuity vision and eye movements. A preferred retinal locus (PRL) is eventually adopted for fixation and oculomotor reference, but individuals still struggle with daily-living tasks as they are sometimes unaware of the location and extent of their scotoma. Here, we use a visual search task to investigate how saccades compensate for the scotoma, which obscures parts of the visual scene. Four individuals with binocular scotomas (BinSc) and 4 age-matched controls participated in our study. We first extensively mapped the BinSc with an eyetracker while fixation was carefully monitored as reported previously. Participants then completed a visual search task where 0, 1, or 2 Gaussian blobs were distributed randomly across a natural scene. Participants reported the number of blobs after 10s of actively searching the display. Search accuracy was principally impacted by the size of the BinSc. All participants made mostly horizontal saccades, but individuals with BinSc made significantly more saccades toward their scotoma than controls for the same directions. Median saccade amplitude was smaller for individuals with BinSc and therefore, when directed toward the scotoma, saccades were aimed more at the scotoma edge closest to the PRL. Thus, multiple sequential saccades were necessary to fully uncover the region hidden by a large scotoma. Instead of adopting such a strategy, participants frequently made backward saccades directed to newly uncovered regions. Critically, this tendency was more likely following a saccade toward the BinSc rather than toward an already visible region. Individuals with BinSc seem to adopt a strategy to explore locations uncovered by having previously looked toward their scotoma. Our extensive analyses of saccade characteristics during visual search was made possible by the detailed mapping of the shape, size and location of the binocular scotoma.

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Poster Session H > Eye Movements: Neural mechanisms > Poster H17

Spatial resolution of pre-microsaccadic perceptual enhancements across the foveola

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We previously showed that before the onset of a microsaccade, fine spatial vision is enhanced at the microsaccade goal. In this study, we investigated the spatial resolution of this phenomenon and examined to which extent this enhancement spreads to foveal locations surrounding the microsaccade target. In addition, we examined how microsaccade preparation impacts sensitivity at the preferred locus of fixation where fine spatial vision is highest. Observers (n = 7) fixated on a marker surrounded by eight location placeholders presented foveally and arranged in a circle (20’ radius). Observers were then instructed to shift their gaze at the location indicated by a central saccade cue. Subjects naturally used microsaccades to relocate their gaze. Nine probes (7’x2’ tilted bars) were briefly presented, one at each location and one at the center of gaze, before the onset of the microsaccade. After microsaccade landing, a response cue appeared. Observers reported the orientation of the probe previously presented at the location indicated by the response cue. Our findings show that pre-microsaccadic enhancements of sensitivity are limited to the microsaccade goal: decrease in performance was observed at the locations surrounding (7’ edge-to-edge distance) the microsaccade goal (1.9 vs. 0.4 and 0.3 d’, $p < 0.002$). Furthermore, before microsaccade onset, observers’ sensitivity at the center of gaze decreased by more than half compared to baseline. We also observed a vertical vs. horizontal meridian asymmetry in foveal sensitivity: observers’ performance at baseline was higher for stimuli presented at locations along the horizontal than the vertical meridian ($p < 0.002$). This asymmetry, however, was reduced right before the onset of microsaccades. These findings show that pre-microsaccadic enhancements of fine spatial vision are highly localized in the foveola, and that microsaccade onset is preceded by a drop of sensitivity at the preferred locus of fixation.

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Spatial Vision: Neural Mechanisms 1

Poster Session H > Spatial Vision: Neural Mechanisms 1 > Poster H18

A large-scale standardized survey of neural receptive fields in an entire column in mouse V1

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The organization and properties of the neural receptive fields in the visual cortex is a prominent factor in understanding the mechanism of neural coding. Here, we perform a systematic and standardized analysis of the structure, organization and properties of the receptive fields in the pan-excitatory neuronal population in the mouse primary visual cortex (area V1). We collected and analyzed a large-scale 2-photon volumetric imaging dataset from an 800x800x600 µm^3 volume in V1 of two mice. The visual responses from were recorded during presentation of a locally sparse noise stimulus to efficiently reconstruct the neural receptive fields. The locally sparse noise stimulus consisted of 9 degree black or white spots on a mean luminance gray background presented at ~3Hz. We designed and implemented a computational pipeline to identify responsive trials, ON and OFF subfields and their geometric properties. Using these experimental and computational pipelines, we found that OFF subfields tended to have larger areas than ON subfields, particularly in layer 2/3. On average, OFF subfields were 15.6 degree^2 larger than the ON subfields across all imaging depths. We also found that the average receptive field area decreased as a function of cortical depth. ON and OFF subfields in layer 5 were on average 22% (ON subfields) and 31.5% (OFF subfields) smaller than those in layer 2/3. Additionally, we found that the responsiveness rate to the sparse noise decreased in deeper layers of cortex. Neurons in layer 2/3 were about 4 times more likely to respond to our visual stimulus compared to neurons in layer 5. Our results provide a systematic and standardized survey of the receptive field properties in V1. The dataset and computational pipeline could serve as a valuable resource to the community to further study the visual responses of neurons in V1.

Poster Session H > Spatial Vision: Neural Mechanisms 1 > Poster H19

Using classification-based decoding to analyze the Spatiotopic and Retinotopic memory representations in primates

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Studies show that a successful visually guided behaviour depends on the target's spatiotopic position. Targets can be encoded and retrieved from memory (decoded) to perform different tasks. However, whether "this retinotopically encoded information transforms to spatiotemporal encoded representations before residing in memory" is not investigated thoroughly. This study aims to explore how accurate the retinotopic representation derives from spatiotopic encoding. We designed a task in which the spatiotopic and retinotopic encoding targets were evaluated on the same trials. The extra-cellular activity was recorded by inserting two 10x10 multi-electrode arrays in the dorsal and ventral circumvolutions of the lateral prefrontal cortex (area 8a, and 9/46, respectively) in two rhesus macaque monkeys. For example, an animal can remember the spatiotopic location of a stimulus in a particular position on display that leads to a success-based reward. However, does the animal keep the target's location as a retinotopically-encoded representation or a spatiotopic one? A classification-based decoding method was employed on single-cell recordings to show spatiotopic and retinotopic representations of a target. Albeit the results' accuracy in decoding retinotopic representations were higher than spatiotopic ones, the lower accuracy in spatiotopic location retrieval can be attributed to the specific brain areas where the cell recordings were performed. Additionally, our results indicate that spatiotopically-positioned targets are encoded as well as the retinotopic encoding. Different classification techniques were used (decision tree vs linear discriminant analysis), and the results show that each method responds better to a specific encoding in both spatiotopic and retinotopic frames of reference, respectively.

Acknowledgements: NSERC

Poster Session H > Spatial Vision: Neural Mechanisms 1 > Poster H20

Diffeomorphic Registration of Retinotopic Maps with Quasiconformal Mapping

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Human visual cortex consists of multiple functional areas. Identifying these visual areas is an essential topic in vision science. Retinotopic mapping (RM) with functional magnetic resonance imaging (fMRI) provides a non-invasive method to define the visual areas. It is well known from neurophysiology studies that retinotopic mapping is diffeomorphic within each cortical area (i.e., differentiable and invertible). However, because of the low signal-noise ratio of fMRI, retinotopic maps from fMRI are often not diffeomorphic, making it difficult to delineate the visual areas' boundaries. We designed a registration framework with quasiconformal mapping to produce diffeomorphic registration of retinotopic maps: (1) generating a diffeomorphic template based on the retinotopic map of mean fMRI signal in Human Connectome Project (HCP), (2) formulating the registration problem as finding a quasiconformal map that maximizes the alignment of the visual coordinates between each RM and the template, and (3) iteratively improving the registration function by regularizing Beltrami coefficients (a representation of quasiconformal mapping). Because quasiconformal mapping is inherently diffeomorphic, the registration is diffeomorphic. We evaluated registration errors produced by several registration methods on a synthetic retinotopic dataset. The results showed that the proposed method produced the smallest registration errors compared to the state-of-the-art methods, including thin-plate spline registration, Bayesian analysis, diffeomorphic demos, and large deformation diffeomorphic metric mapping. We also applied our method to the retinotopic data from HCP. Compared to the visual coordinates' misalignment based on structural registration, the method reduced the misalignment by ~2.7%, meaning the method generated a better registration. In addition, the method provided better boundary delineation of visual areas. The proposed method improved low-quality RM and can also be used to improve RM templates.

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Quantitative Characterization of the Human Retinotopic Map Based on Quasiconformal Mapping

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Visual perception and cognition involve a cascade of geometric transformations from the retina to high-level cortical areas. Yet, our perception is mostly veridical and is largely invariant across individuals. The transformation from the retina to the primary visual cortex (V1) has been modeled using conformal and quasiconformal maps with the latter being a better fit to empirical retinotopic maps. However, we have not actually quantified the transformation to understand their effects in the cascade. We developed a new quantification framework for retinotopic maps based on computational conformal geometry and quasiconformal Teichmüller space theory. There are three key components: (1) pre-processing retinotopic maps to ensure that they preserve topology despite the low spatial resolution and low signal-to-noise ratio of retinotopy data, (2) quantifying the mapping between the retina and V1 (conformal or not conformal) using Beltrami coefficients, (3) developing mathematical and numerical methods to ensure the quantification is completely invertible (forward and backward transformations between visual areas). The result was a "Beltrami coefficient map" (BCM) that allowed us to measure and compute the forward and backward transformations between the retina and V1. We applied the new framework on the V1 retinotopic maps from the Human Connectome Project (n=181), the largest state of the art retinotopy dataset currently available. The average measurement of "distortion" on the left and right BCM had values of 0.310 ± 0.110 and 0.312 ± 0.105, respectively (range: $0 \le x < 1$, with 0 being most conformal). We showed that the transformation from the retina to V1 is quasiconformal. Does it mean that later stages of visual processing can "correct" the distortions to generate veridical perception? How do visual or neural disorders affect the

transformations? Future applications of this mathematical framework to all the visual areas may shed some new light on these questions.

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Poster Session H > Spatial Vision: Neural Mechanisms 1 > Poster H22

Development of the visual pathways predicts changes in electrophysiological responses in visual cortex

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The latency of neural responses in visual cortex varies dramatically among individuals and changes systematically across the lifespan. Does maturation of the visual pathways predict changes in electrophysiology? Here we test the hypothesis that development of the optic radiations mediates developmental changes in conduction velocities of visual signals. Thirty-eight children participated in a cross-sectional study including a diffusion MRI and an MEG session (17 females, mean age: 9.5 y, SD: 1.6, age range: 7-12 y, between-sessions time gap: 0-35 dd). During the MEG acquisition participants were presented with a sequence of high and low contrast visual stimuli (HC and LC), including words and noise patches. A fixation and a lexical decision task were performed on the same stimuli in alternating runs. For all stimulus types and tasks, early evoked fields were observed around 100 ms after stimulus onset (M100), with a reduced amplitude and longer latency for low as compared to high contrast images. The left and right optic radiations (OR) was identified in each individual's brain based on anatomically constrained probabilistic tractography and mean fractional anisotropy (FA) was calculated for each pathway. OR FA predicted electrophysiological characteristics of M100 responses, and this was particularly clear in high contrast stimuli: the greater the OR FA the faster the M100 latency and the bigger its amplitude. Moreover, a time-frequency decomposition of the M100 response revealed that participants with higher OR FA had greater power and inter-trial coherence. Examining changes over this developmental window, the M100 peak latency to HC became faster with age and the FA of the optic radiation fully mediated this effect. Similar FA mediation effects were found for the M100 amplitude and power. These findings suggest that development of the optic radiation over childhood accounts for individual differences in the developmental trajectory observed in early visual evoked responses.

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Poster Session H > Spatial Vision: Neural Mechanisms 1 > Poster H23

Assessing the general utility of a probabilistic atlas for independent delineation of early visual areas

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The human brain contains many different regions defined by sensory neural responses and anatomical landmarks. FMRI allows for non-invasive investigation of how various sensory inputs correspond to their cortical representations. Accurate and reliable identification of these cortical regions in individual subjects is essential for group-level analyses, but individual delineation of regions of interest (ROIs) is not always feasible in studies with large datasets or missing data. In this work, we examined the retinotopic fMRI responses within visual cortex to assess the general utility of a publicly available probabilistic atlas (Wang et al., 2015) for independently identifying three important topographic areas in the visual system: V1, V2, and V3. We modified a standard population receptive field (pRF) mapping protocol by systematically modulating the stimulus flicker frequency and the types of objects that composed the bars of visual stimuli

sweeping across the visual field. We also included motor cues and auditory stimuli in the pRF protocol. Twenty-five neurotypical adults completed two five-minute pRF scans at 7 Tesla (1.6 mm isotropic resolution). Robust motor, auditory, and retinotopic mapping were observed in the expected cortical areas. In our sample, we found reliable agreement between independent V1 identification based on structural MRI data and the expected fMRI response. However, we found significant discrepancies at the individual subject level between the independent atlas definition of the V2 and V3 boundaries and the fMRI response. These results emphasize the continued need for visual inspection of ROIs in visual cortex and validate a protocol that allows efficient and automated mapping of visual, auditory, and motor representations.

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Poster Session H > Spatial Vision: Neural Mechanisms 1 > Poster H24

Multi-voxel pattern analysis of center-surround processing in psychosis

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Psychosis involves abnormal sensory percepts, including hallucinations and more subtle differences in visual perception. A number of disorders are associated with psychotic symptoms, including schizophrenia (SZ), schizoaffective disorder (SA), and bipolar disorder (BP). Past studies have suggested that patients with psychosis demonstrate weaker surround suppression and reduced contrast sensitivity compared to controls. We tested for these effects by examining activity patterns across voxels with a decoding analysis (multi-voxel pattern analysis) as part of the ongoing Psychosis Human Connectome Project. High field (7 tesla) fMRI and behavioral data were collected during a visual contrast discrimination task. Small circular gratings were presented at four contrast levels (10, 20, 40, & 80%), each with and without a surrounding annular grating. FMRI responses were extracted from a retinotopically mapped region of primary visual cortex corresponding to the target gratings. We used support vector machine decoding with 5-fold cross validation to investigate differences in visual processing between people with psychosis, their first-degree relatives, and healthy controls. We expected less accurate decoding of conditions with and without surrounding stimuli, and lower decoding accuracy for contrast in people with psychosis compared to controls. Decoding accuracy rose above chance levels following stimulus presentation and declined following stimulus offset. Preliminary results show peak decoding accuracy for the presence versus absence of a surround was significantly higher in controls compared to participants with psychosis, consistent with our first hypothesis. However, we did not observe a significant difference in peak decoding accuracy between groups when decoding stimulus contrast. Our results suggest that psychosis is related to a reduction in the fidelity of information about surrounding stimuli in primary visual cortex.

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Poster Session H > Spatial Vision: Neural Mechanisms 1 > Poster H25

Stronger BOLD responses along the horizontal meridian in V1

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In three previously collected neuroimaging datasets (HCP 7T Retinotopy, n = 181; Temporal Decomposition through Manifold Fitting, n = 5; Natural Scenes Dataset, n = 8), we find large asymmetries in the magnitude of the BOLD response in primary visual cortex (V1): stimulus-evoked BOLD responses, expressed as percent change above baseline, are up to 50% stronger along the representation of the horizontal meridian compared to the vertical meridian. While this effect is quite robust, it remains unclear whether magnitude differences in the BOLD signal between locations can be interpreted as differences in local neural activity. To investigate this issue, we systematically evaluated the potential contribution of a number of non-neural factors to the observed effect, including cortical thickness, cortical folding, cortical depth, and vasculature. We find that only two of these factors have substantial relationship to the size of BOLD responses: cortical thickness and presence of macrovasculature (as indexed by T2*-weighted signal intensity). The relationship generalizes across subjects and brain regions, indicating that variation in BOLD response magnitudes

across brain locations partly reflects differences in cortical thickness and vascularization. To compensate for these confounding factors, we then implement several regression-based correction methods and show that BOLD responses, after correction, become more spatially homogeneous. However, even after correction, BOLD response asymmetries in V1 still persist. This suggests a genuine neural substrate for previously reported asymmetries in behavioral performance, wherein performance is best along the horizontal meridian (Carrasco et al., Spatial Vision, 2001). More broadly, these results enhance the ability of neuroscientists to make correct inferences about local neural activity from fMRI data.

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Plasticity and Learning 2

Poster Session H > Plasticity and Learning 2 > Poster H41

Gaining the system: population limits on compensating color deficiencies through gain control

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A number of studies have found that the supra-threshold color responses of anomalous trichromats are stronger than predicted from the reduced spectral separation of their longer wave cone pigments. These compensatory effects could occur if post-receptoral neurons amplify their gain to discount the weaker difference signal provided by the cones. However, this compensation is typically incomplete, and the factors that limit it are not well understood. We modeled the consequences of color deficiencies and gain changes within a population code for cortical color vision to assess the impact of adaptation at different stages. P cells carrying LvsM signals are also responsive to luminance (L+M) contrast, and there is evidence from both humans and primates that they do not adapt to a color vision loss. The weaker LvsM signal in anomalous trichromacy will therefore bias the distribution of cell preferences away from the LvsM and toward the L+M axis. Gain changes occurring subsequently in the cortex could restore the average responses in individual neurons, but would not undo the biases in the population response. For example, even if cells tuned to pure LvsM signals fully recovered their response, the population as a whole would still carry weaker LvsM signals. Models of these response changes show that this can lead to partial recovery of the LvsM responses in anomalous trichromats, but also predicts increased responses to luminance contrast, consistent with improved luminance sensitivity in color deficient observers (e.g. Doron et al. 2019). Gain changes that instead occurred later, e.g. after combining signals from the LvsM and S cones, predict enhanced responses to S-cone mediated signals, which are not observed. These analyses constrain the potential sites and mechanisms of compensation for a color loss, while also pointing to testable predictions about how color signals (e.g. contrast) are represented within the population.

Poster Session H > Plasticity and Learning 2 > Poster H42

Evidence for the McCollough Effect in Primary Visual Cortex

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Viewing colorful oriented gratings produces color aftereffects that appear in conjunction with a particular orientation. A widely studied example is the McCollough Effect (ME), an illusion characterized by very long-lasting aftereffects. Its neural locus, however, remains mysterious. We used fMRI to investigate this question. Six participants completed 2 scan sessions. In a first, baseline session, participants viewed an array of square wave gratings at 2 orientation pairings (0-deg/90-deg and 45-deg/135-deg) and 2 color pairings (black/white and black/color). The blocks with color were intended to simulate the ME, with contrasts roughly matching the strength of the induced effect. Prior to the second session, we induced the ME with an augmented-reality “McCollough World” method, wherein participants viewed a filtered version of the world through a head-mounted display with an attached camera. Images recorded by the camera were filtered in the Fourier domain to only pass narrowband horizontal or vertical energy, and high-contrast red or green was added. The feed presented to participants switched between color and orientation pairings every 2 sec. (i.e.

green/horizontal, red/vertical), and participants viewed videos in this environment for 2 hr. Participants were then immediately scanned using the same paradigm from session 1, with added 3 min. adaptation top-ups between runs. The ME was expected to enhance the color of red/green gratings whose orientation was congruent with it, while in incongruent red/green gratings the ME was expected to cancel their color. We used an atlas-based method to delineate primary visual cortex (V1), and performed multivariate pattern classification of red/green vs black/white on voxels in that region. For 5 of 6 participants, inducing the ME increased the frequency that congruent gratings were classified as red/green, and conversely, increased the frequency that incongruent gratings were labeled as black/white. This pattern provides evidence that the McCollough Effect arises as early as V1.

Acknowledgements: NSF-BCS 1558308, F32 EY031178-01A1

Poster Session H > Plasticity and Learning 2 > Poster H43

Hour-long color adaptation gradually expands perceptual color space

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When the environment changes color, for example after putting on tinted glasses, the visual system adapts, and the world regains ‘normal’ appearance. For strong shifts, adaptation may progress over hours, but little work has measured its long-term time course. We studied this adaptation by reconstructing subjective color space using multidimensional scaling (MDS), to characterize its perceptual consequences for a large range of colors. Seven observers wore bright red glasses for 1.5 hr. Color perception was measured before and immediately after observers put the glasses on, after 45 min, and 1.5 hr of wear. Observers viewed pairs of filled color circles, 1.5 degrees in diameter, centered within a 6-degree black square on a naturalistic background image. Thirteen colors were chosen from two concentric circles in LAB space comprising unique and intermediate hues at two saturation levels, and one gray. Observers rated the difference between each possible color pair on a scale of 0 (identical) to 9 (largest difference). Metric MDS was used to reconstruct perceptual spaces from measured dissimilarity matrices. We delivered glasses and color-calibrated laptops to observers, who participated at home. Wearing red glasses caused the world to subjectively appear very reddish, and all pairs of colors were rated as relatively similar. As observers adapted, colors subjectively regained more normal appearances, and the dissimilarity between color pairs gradually increased. In the MDS solutions, the mean pair-wise Euclidean distance between all color pairs increased significantly during the first 45 min, from 3.03 to 3.68 ($p < 0.01$), and further increased to 4.20 by the end of 1.5 hr ($p < 0.1$). The results indicate that hour-long color adaptation expands the perceptual color space, in addition to recalibrating the perceived neutral point (shown in past work). Future work can model the mechanisms underlying the time courses of these effects.

Acknowledgements: NSF-BCS 1558308

Poster Session H > Plasticity and Learning 2 > Poster H44

New evidence for preservation of conditioned behavior based on UV light sensitivity in dissected tail halves of planarians

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[Introduction] Planarians are well known for its abilities of bidirectional regeneration and basic learning such as habituation and conditioning. Our pilot observations suggest that (a) UV light is more stimulating than non-UV light, sensed by UV opsins distributed across the entire body, and (b) response to UV light (wiggling) and that to an electric shock (immediate contraction) are qualitatively different. Based on these, we reexamine Pavlovian conditioning to see if a tail half of a conditioned planarian can retain learned behavior after dissection. [Method] 20 planarians in the experimental group were instilled with a Pavlovian conditioning procedure, in which weak UV light was paired with an electric shock with a 3 second onset delay (but overlap). The weak UV, a neutral stimulus, intrinsically leads to a wiggling/swimming response but typically after 10-15 seconds. The electric shock, the unconditioned stimulus, leads to an immediate contortion/constriction (Unconditioned Response). After training (weak UV followed by electric shock) 20 times x 7 days, they started contorting (Conditioned Response) to the UV stimulus alone, at which point, they were dissected. After 4 days (to regenerate motor functions post-dissection), they were tested twice a day with the same UV light alone. The control group underwent the same procedures as the experimental group except for conditioning (UV+electric shock). [Results] A total of 16 out of 20 planarians showed the CR, i.e. contortion/constriction to the UV. The tail halves in the control group continued to show slow wiggling responses but not CR. [Discussion] The results suggest that planarians have a structure other than its ganglia that retains learned effects, which is consistent with the latest evidence with habituation (Shomrat et al., 2013). Since UV sensitivity distributes in the entire body, it opens up the possibility of retention and execution without the ganglia.

Acknowledgements: Masason Foundation Support fellowship

Poster Session H > Plasticity and Learning 2 > Poster H45

Evidence for sequential reading effects in screening mammography

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Screening mammography represents a difficult visual task with significant consequences for the women being screened. It is common for radiologists to read screening mammograms in batches of cases, which opens the possibility for sequential effects from a variety of sources including adaptation to previous cases. Adaptation has been shown to influence the perception and analysis of mammographic images in controlled experiments with non-radiologists, but it remains uncertain how it manifests in practice. We analyzed mammography readings from an observational study in the Netherlands to evaluate possible sequential effects. The study acquired probability of malignancy (PoM) scores and response timestamps during actual mammographic interpretation for 21 radiologists and over 41,600 cases in the Dutch national screening program. We defined a batch of cases for each reader as those interpreted between breaks of more than 10 minutes in sequential timestamps. This gave an average of 14.3 batches per radiologist, and an average batch length of 138.6 cases. The inferred recall rate (true-positive and false-positive interpretations) averaged across radiologists was 2.4%, identical to the reported recall rate for the Dutch breast-cancer screening program. The median reading time, averaged across radiologists, was 19.4 s per case. To evaluate sequential effects, we tested for systematic changes in PoM scores, recall rates, and reading times as the radiologists progressed through the batches. Nonparametric permutation tests were used to establish significant observations. The first 2-3 cases in the beginning of a batch had higher PoM scores and substantially higher recall rates before settling into relatively consistent behavior near the overall averages. Reading times appeared to decay steadily over the first 15 to 20 cases in a batch. Radiologists thus show clear evidence of sequential reading effects over the course of a batch, consistent with the hypothesis that they are adapting to visual properties of the mammograms.

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Poster Session H > Plasticity and Learning 2 > Poster H46

On the Relationship between Perceptual Learning and Statistical Learning: Evidence from Coherent Motion Detection

View Poster | Visit me in Gather.Town Manatee Room on Tuesday 3:00 pm - 5:00 pm EDT

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Background: What is the relationship between perceptual learning (PL) -- improvements in information pickup as a result of experience -- and statistical learning (SL) -- representing co-occurrences among environmental features? We investigated this question using signal detection theory methods in a paradigm that could allow both. Design: Pretest and posttest phases consisted of a coherent motion detection task: Participants observed random dot kinematograms (RDK) showing fields of dots moving mostly in random directions, but with one subset of dots moving coherently in a single direction. Participants adjusted a dial to indicate the direction of coherent motion on each trial. The training phase, between pretest and posttest, consisted of a motion discrimination task: On each trial, participants observed two sequential RDK displays, each with motion in a single coherent direction, and indicated whether the two displays showed motion in identical or different directions. The directional difference between intervals was adjusted during training using a staircase procedure to maintain 75% accuracy, with adjustment occurring every ten trials. For each participant, all discrimination trials were clustered around a constant direction; this basic direction was chosen from among 8 possible directions, separated by 45 deg, and randomized across participants. Feedback was provided after each response. Results: Preliminary results showed reliable transfer of PL effects from the motion discrimination task to improved sensitivity in the posttest to coherent motion, with these effects mostly confined to each participant's training direction. Consistent SL effects were shown by criterion changes toward responding to the general direction of motion used in training. We will discuss correlational methods for assessing whether these are linked or independent processes. Conclusions: PL and SL can occur in the same learning context, with PL effects shown as sensitivity changes and SL effects as criterion changes. These two learning processes may proceed concurrently but separately.

Poster Session H > Plasticity and Learning 2 > Poster H47

Modeling visual perceptual learning of Contrast Discrimination with Integrated Reweighting

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The Integrated Reweighting Model has been used to replicate a variety of phenomena in Visual Perceptual Learning, or VPL. These phenomena include learning, location specificity (Dosher et al 2013, PNAS), and even roving (Dosher et al 2020, JOV). While the phenomena that have been replicated span many of the important characteristics of VPL, the tasks replicated have been primarily constrained to single forced-choice orientation discrimination tasks. Here we demonstrate a twin network modification to the model allows it to perform a 2-AFC (alternative forced choice) contrast discrimination task. Thus, as compared with previous versions of the model that focused primarily on orientation judgements of single images, this modification expands the model in capability both to 1) compare two separate images and to 2) make contrast judgments. The twin network methodology uses two parallel instantiations of a variant of the classic model whose outputs are then compared. This model thus offers each trail, in the case of contrast discrimination, an estimate of which image has higher contrast. Here we test this model in a classic behavioral contrast discrimination protocol inspired by Yu et al in 2004 in JOV. The similarity to classic protocols in VPL is made possible by the twin network instantiation of the integrated reweighting model. Expanding the capability of classic models is critical for determining their utility as models for the human visual system.

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Poster Session H > Plasticity and Learning 2 > Poster H48

Multi-location, two-interval paradigms can overcome roving costs – an explanation of Xie & Yu (2020) data by an extended Integrating Reweighting Theory (IRT)

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Perceptual learning is often slowed or eliminated when task variants are intermixed —so called task roving. We (Dosher et al., 2000) recently showed dramatically slower learning when four different orientation discrimination tasks were intermixed (+/-12deg from 4 separated axes), relative to training either with identical or sufficiently different axes in all four locations. A computational framework, the IRT, successfully modeled the pattern of results. A similar study (Xie &

Yu, 2020) also intermixed training of four orientation discrimination tasks in twelve locations. Structurally, the two studies are similar—but here robust learning occurred, with transfer to an untrained task-and-location combination. We suggest that the key contrast reflects the use of a two-interval design vs the more commonly used single interval identification design. (The tasks also differ in using orientation difference thresholds versus contrast thresholds.). In this study, we create a new extension of the IRT for the two-interval design and provide an excellent fit to the four training conditions of Xie and Yu: learning where the locations/tasks shift predictably from trial to trial, where the locations/tasks are randomized over trials, where the training location/task is the same as in pre- and post- tests, and a control condition that measures only transfer without training, reproducing both the empirical learning and transfer effects. In the new IRT model extension, the activations in four mini-decision units (driven by connections from location-specific and location-invariant orientation tuned representations) from the first interval are stored and compared to those in the second interval. Capitalizing on these two-interval comparisons avoids the roving disruption; location-invariant learning from multiple locations enables transfer. We propose the new IRT as a computational framework for perceptual learning in two-interval designs that can be put to additional empirical tests to understand the differences or similarities in perceptual learning in single- and two-interval tasks.

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Poster Session H > Plasticity and Learning 2 > Poster H49

Hierarchical Bayesian modeling of mixed training accuracy effects in perceptual learning

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Liu et al. (2012) found that mixing high and low accuracy training led to significant perceptual learning without feedback in a Gabor orientation identification task based on block-by-block learning curves. In this study, we developed and fit a hierarchical Bayesian model (HBM) to the trial-by-trial data in all six groups (mixtures of high-high, high-low, and low-low training accuracies, with and without feedback) in Liu et al. (2012) to estimate the posterior distributions of the parameters and hyperparameters of the learning curves as well as their covariances at both the subject and group levels. The learning curves were modeled as exponential functions with three parameters: time constant (TC), and initial and asymptotic thresholds. We computed the distributions of the means (M) of the parameters of the learning curve as well as learned threshold reduction (d'=M/SD) for each group. Based on the 95% confidence interval of the d' distributions, we found significant learning in the high-high with (0.17±0.04 log10 units; d': 6.00±2.59; TC: 377±73 trials) and without feedback (0.25±0.07 log10 units; d': 3.70±1.60; TC: 427±67 trials), high-low with (0.17±0.05 log10 units; d': 4.30±1.81; TC: 418±69 trials) and without feedback (0.22±0.06 log10 units; d': 4.80±1.90; TC: 419±69 trials), and low-low with feedback (0.18±0.05 log10 units; d': 4.8±2.11; TC: 368±74 trials) groups, but no significant learning in the low-low without feedback (0.08±0.07 log10 units; d': 1.7±1.43) group. In addition, the magnitudes of learning and time constants were not significantly different among the five groups with significant learning. Although the results were qualitatively consistent with Liu et al. (2012), the new trial-by-trial analysis yields the joint posterior distributions and specifies both group- and subject-level performance and variability, and characterizes the individual and the group learning in one unified model that accounts for the full data set.

Acknowledgements: Supported by the National Eye Institute (EY017491).

Poster Session H > Plasticity and Learning 2 > Poster H50

Hierarchical Bayesian modeling of training accuracy and feedback interaction in perceptual learning

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Based on an analysis of the block-by-block learning curves, Liu et al. (2010) found that, although it was not necessary for perceptual learning at a high training accuracy, feedback was critical at a low training accuracy in a Gabor orientation identification task. In this study, we developed a hierarchical Bayesian model (HBM) to analyze the trial-by-trial data in Liu et al. (2010) to estimate the joint posterior distributions of the parameters and hyperparameters of the learning curves as well as their covariances at both the subject and group levels. The learning curves were modeled as exponential functions with three parameters: initial and asymptotic thresholds, and time constant (TC). We used the posterior distributions of the hyperparameters to compute the distributions of the mean (M) learning parameters as well as threshold-reduction learning effects (d'= M/SD) at the group level. Based on the 95% confidence interval of the d' distributions, we found significant perceptual learning in the low training accuracy with feedback (0.15±0.06 log10 units; d': 3.2±1.40; TC: 372±84 trials), high training accuracy with (0.20±0.04 log10 units; d': 6.1±2.23; TC: 364±70 trials) and without feedback (0.11±0.05 log10 units; d': 3.3±1.46; TC: 366±83 trials) conditions, but no significant learning in the low training accuracy condition (0.02±0.06 log10 units; d': 0.4±1.45). In addition, the magnitudes of learning and time constant were not significantly different among the three conditions that led to significant learning. Although the pattern of results was qualitatively the same as Liu et al. (2010), the trial-by-trial HBM model allowed us to quantify both individual observer and group variability in the full dataset in one unified model, characterizing the general properties of the learning curves at both levels simultaneously. The model also produces posterior distributions on parameters in all groups that can be used as priors for future Bayesian analyses.

Acknowledgements: This research was supported by the National Eye Institute (EY017491).

Poster Session H > Plasticity and Learning 2 > Poster H51

Enhancing Perceptual Learning Through Adaptive Comparisons

View Poster | Visit me in Gather.Town Manatee Room on Tuesday 3:00 pm - 5:00 pm EDT

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One driver of perceptual learning (PL) in complex domains is the development of selective extraction of information that distinguishes different categories (Gibson, 1969). Between-category comparisons have been shown to improve this component of PL (Kang & Pashler, 2011; Higgins & Ross, 2011), particularly when the compared items are similar (Dwyer & Vladeanu, 2009). Here, we ask whether adaptive methods that use learner performance can further enhance the benefits of comparisons. We used a face identification paradigm with 22 categories of faces, each containing five unique exemplars of one individual (Min, Kose, & Dugelay, 2014). In Experiment 1, training was structured such that on standard trials a single face image was presented and learners attempted to select the correct name. Adaptive schedules in the ARTS system (Mettler, Massey & Kellman, 2016) guided category spacing based on learner performance. In one condition, two sequential errors involving the same pair of categories led to an adaptively triggered comparison trial (ATC condition). On ATC trials, participants were presented with a name and instructed to choose between two exemplars from the confused categories before resuming standard trials. In Experiment 2, we compared an ATC condition to a control condition containing the same number of random comparison trials (exemplars from randomly selected categories). All participants learned to mastery criteria of accuracy and fluency and completed immediate and delayed (one-week) posttests. Efficiency scores -- defined as posttest accuracy divided by the number of learning trials invested -- were compared across conditions. In both experiments, the ATC condition required the fewest average trials to reach mastery and resulted in more efficient learning than the control condition. These results suggest that adaptively triggered comparisons enhance the efficiency of PL. Using learner performance to determine the contents and timing of comparison trials can be beneficial in optimizing perceptual category learning.

Acknowledgements: NIH 5R01CA236791

Poster Session H > Plasticity and Learning 2 > Poster H52

Rapid Reorganization of Cerebellar Involvement in Mental Visualization

View Poster | Visit me in Gather.Town Manatee Room on Tuesday 3:00 pm - 5:00 pm EDT

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It is generally understood that the main role of the cerebellum is in movement planning and coordination, but neuroimaging has led to striking findings of its involvement in cognitive processing. Visualization is a key cognitive process in a wide range of ‘internal’ and ‘externalized’ functionalities, from learning and memory to artistic creativity and engineering design. Here we use fMRI and the SUIT toolbox to investigate the involvement of the cerebellum in mental visualization, and Granger Causal connectivity to analyze its progressive interplay with the whole-brain visualization network. For each of a set of complex spatial structures in the form of line-drawings, sighted adults performed in a 3T scanner i) visual exploration (30s) and ii) visualization-from-memory of the explored images (30s), interleaved with fixation periods (20s); each scan consisted of three repeats of this sequence. A well-structured visualization network of activated and suppressed regions was identified in the cerebellum. The change in activation with the visualization and perceptual exploration repeats in each region-of-interest (ROI) was analyzed to define the temporal evolution of the rapid learning process. In visualization, positive caudal cerebellar ROIs showed significant increases in the level of activation as the learning progressed across repeats, while negative Crus I/II ROIs showed significantly increased negative signal, implying a progressive differentiation of the cerebellar responses; comparative analysis of the exploration revealed an interplay of overlapping and contrasting learning effects. The causal connectivity analysis uncovered a characteristic dynamics of cross-coupling between key cerebellar ROIs and large-scale brain networks, such as the default mode network (DMN). These multidimensional fMRI and connectivity findings laid a solid basis for a novel framework of rapid cerebro-cerebellar reorganization. They provide important insights into fundamental questions of cognitive cerebellar function, and also have implications for the development of practical methods for enhancing the cognitive abilities of learning and memory.

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Scene Perception: Models and statistics

Poster Session H > Scene Perception: Models and statistics > Poster H53

Sampling Human Visual Experience Through Text and Media Messages

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How do locations, actions, and goals interact to affect how we categorize our environments? Recent work has shown that scene categorization is mainly a high-level process focusing on high-level properties like objects and attributes that are processed iteratively with their settings. Additional progress on this topic has been limited by a paucity of data on where people spend their time and the types of activities done in these different locations. This study sought to investigate how observers’ locations, actions, and goals influenced the scenes they categorized throughout the course of a month. We uncovered which actions or goals were most commonly associated with certain locations and vice versa. We did this by conducting a virtual study in the month of December 2020 involving ten participants residing in Maine with ages ranging from 20 to 53. Participants received ten daily text messages that asked them to specify their present environment or send a picture of their location, identify the action they were performing, and describe the goal they were trying to achieve. The results suggest that all participants spent the majority of their time inside. The data revealed that 90.9% of all locations participants reported were inside, 3.4% were in a car, and 5.7% were outside. There was a numerical tendency to spend more time indoors with increasing age (R = 0.06). Participants partook in 157 unique activities/goals. The most frequent activity reported was working, followed by relaxing, eating, cooking, and watching videos. The frequency of activities exhibits a power law distribution that obeys Zipf’s law. This study provides more insight into how humans categorize scenes, and the data helps identify which scenes are most commonly experienced by humans on a daily basis.

Acknowledgements: This material is based upon work supported by the National Science Foundation under grant no. 1920896 and Bates College

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Measuring the 1/f spatiotemporal amplitude spectrum of the DynTex database

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It is well established that natural scenes have a 1/f drop off of spatial and temporal frequencies. The exponent or slope of this drop off has often been reported as being equal to 1. However, more recent work in the spatial domain has revealed that only a few natural scenes conform to this value. Instead, photographs of natural scenes on average have a slope ~1.2, and can range between 0.8 to 1.4. It is currently unknown whether this is also the case in the temporal domain, as to the best of our knowledge, an analysis of a wider range of natural movies has yet to be conducted. Here we measure the 1/f spatiotemporal amplitude spectrum of movies in the DynTex database—a freely available dynamic texture database. We manually labelled a subset of movies across three categories: 1) Natural – containing mostly natural objects, 2) Mixed – containing a roughly equal mix of natural and man-made objects, 3) Unnatural – containing mostly man-made objects. Across the three categories, we found large variance in both spatial and temporal slope measurements. In the spatial domain, our findings closely correspond to past research where the slope in the Natural category was ~1.1 on average, but had a wider range between ~0.6 to 1.9. In the temporal domain we found that the slope in the Natural category was ~0.5 on average, and ranged between ~0.0 to 1.1. Mixed and Unnatural categories had significantly different spatial and temporal slope measurements, where slopes on average were steeper spatially (~1.3) and shallower temporally (~0.4). The temporal slope measurements in the Natural category notably differ from past research. This finding may be unique to the database analysed, and as such further research is needed to confirm the extent to which 1/f slope in the temporal domain varies in nature.

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Using machine learning to understand human sensitivity to noise in naturalistic images

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Understanding our sensitivity to noise in naturalistic conditions will provide key clues as to the visual system's adaptations to the real world. Determining which characteristics of image noise (kind, amount, or distribution) appear particularly noisy to humans is a key first step. To examine this, we presented pairs of images (natural landscapes: m=102 shot at ground level; m=289 overhead), which were noise-added versions of the same noise-free image and had observers (n=108 total) judge, in a 2AFC paradigm, which image appeared clearer (less noisy). Varying level and kind of noise, data from 2346 image pairs were obtained. Classifiers were trained to simulate human choice data based on the values extracted for each of the image's forty-four pre-determined features. Features are local or global; local meaning over a small neighborhood around each pixel; global meaning ensemble values over the entire image. Results shown here are the averages of four algorithms (decision tree, random forest, logistic regression, SVM). Ten-fold cross-validation was used. Custom code for feature extraction was written in MATLAB; supervised machine learning was implemented on Pycharm. Our reasoning was to use machine learning to mimic human selection, then leverage the classifier to find what image features could possibly underlie human sensitivity to noise. While the all-features classifier matched (95.3±1.2%) human choice data, its performance was nearly matched by a classifier (93.0±1.3%) based on a single local feature, LocalContrastNearestNeighbor-Red – the local (red) contrast between a pixel and its nearest neighbors. The second-best (92.4±1.4%) single-feature classifier was also local. On the other hand, the best single global-feature classifiers, namely NumberOfOutlines (88.0±1.6%), HistogramMean-Red (83.3±1.9%) and HistogramSkewness-Red (82.8±1.9%) did not perform as well. Generally speaking, clearer images as judged by human observers were of lower local contrast and higher positive skewness than their noisier counterparts. Additional signatures of human-like performance are being explored.

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Emergent dimensions underlying human perception of the reachable world

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Near-scale, reach-relevant environments are the interface of our manual interactions with the physical world. Recent efforts have begun to probe perceptual and neural representations of naturalistic visual experience at this scale (Josephs & Konkle, 2019; Josephs & Konkle, 2020). Here, we use a computational approach to uncover major dimensions that can parameterize these spaces and predict human similarity judgments. In a large-scale online experiment, 1.2 million odd-one-out judgments were obtained on triplets sampled from 987 images of reachable-scale spaces (hereafter "reachspaces"), drawn from 329 different categories (N = 3,112 Turkers). This yielded a partial sampling of the similarity structure among the images. We then generated a Sparse Positive Similarity Embedding (Hebart et al., 2020), which is a predictive model of the full similarity structure, in which each image is formulated as a point in a multi-dimensional space, and the dimensions are inferred given sparse and positive encoding constraints. This procedure yielded a 31-dimensional embedding that predicted odd-one-out judgments with 59.8% accuracy (chance=33%, noise ceiling=66.3%). In a validation experiment (N=322), we fully sampled pairwise dissimilarities among a subset of 45 images, and found that this closely correlated with the dissimilarity structure predicted by the model (r = 0.87). K-Means clustering over pairwise dissimilarities derived from the embedding showed two major distinctions among reachspaces: food-related vs non-food reachspaces, and digital vs analogue reachspaces. Additionally, examination of the 31 dimensions comprising the embedding revealed interpretable attributes, e.g. "entertainment-related" (i.e. chessboard, poker table), "navigation-related" (i.e. steering wheels, cockpits), "storage-related" (i.e. drawers, shelves), and "cluttered" (i.e. messy desks or tables). Overall, these dimensions highlight differences in the functions, affordances, and visual appearances of different reach-relevant spaces and suggest that the similarity structure among reachspaces is related to the actions they support. These results provide a novel accounting of the representational structure of the reachable world.

Acknowledgements: This work was funded by an NIH R21 to TK (R21EY031867), and by a Pershing Square Fund for Research on the Foundations of Human Behavior grant to EJ.

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A Performance-Optimized Limb Detection Model Selectively Predicts Behavioral Responses Based on Movement Similarity

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Humans are expert body pose readers. What psychological representations support this feat, and how are they computed? We ask whether a computational model that has been optimized to localize bodily limbs learns representations that provide a good account of human psychological representations of kinematics. The heart of the model, called Openpose (Cao et al., 2019), is a dual-stream architecture that simultaneously detects body parts (in one stream) and associates them into limbs (in another) using part affinity fields—2D vector fields that encode the location and orientation of the limbs. To measure human perceptions of body kinematics, we asked 20 participants to arrange videos of 60 everyday actions based on the similarity of their movements. Then, we asked whether features from the intermediary layers of Openpose (55 layers, concatenated across the two streams) selectively recall the structure in this behavior. We found that representations from Openpose correlated with movement-guided similarity moderately (average r=0.18, p<.001). In addition, this correspondence improved across all layers of the network—especially early layers 1-15. In contrast, these features did not correlate well with human judgments of similarity in the actions' intuitive, unguided similarity (r=0.07), visual appearance (r=0.05), or the actors' goals (r=0.07). Since the early spine of Openpose is an object-recognition network (VGG-19) that has been fine-tuned for pose recognition, we also compared its performance to that of a generic VGG-19 not fine-tuned this way. Features from the generic network showed similar performance patterns to the fine-tuned version for the non-movement tasks, but an opposite pattern for the movement task, with performance dropping across layers 1-15. These results suggest that perceived movement similarity recruits computations and representations more specialized for limb detection than generic object recognition; and, more broadly, that performance-optimized computational pose models provide a useful tool for illuminating body perception.

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Neural Correlates of Efficient Coding of Visual Scenes

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Despite the complexity of scenes, human visual processing is rapid and accurate. A longstanding framework for explaining this feat posits that the brain creates efficient representations of visual inputs by capitalizing on statistical redundancies (Attnaeve, 1954). This framework makes the testable prediction that images that are more redundant (i.e. those with less information) will have a processing advantage over those that are less redundant. As it is difficult to measure the information content of images, this hypothesis has remained open. Here, we reason that one only needs to know the relative amount of information that a scene contains, and that this information can be estimated by examining the relative compression efficacy of off-the-shelf algorithms such as JPEG and PNG. Specifically, more compressible images typically have more redundancy and thus less information. To test for processing differences between images, we computed the mutual information between images and their resulting visual evoked potentials using a state-space framework (Hansen et al., 2019). If early visual processing is information-limited, then we predict that highly compressible images will elicit neural signals with higher mutual information compared to less compressible images. We amassed a database of ~1000 photographs of common, daily content in RAW image format. We compressed each image in PNG (lossless) and JPEG-2000 (lossy) formats and examined the file size differences between original and compressed images. We found that the correlation between PNG and JPEG-2000 compressibility was high (r=0.97). Observers (N=11) viewed 25 of these photographs, each presented 40 times in a random order. We found a positive correlation between the neural mutual information and image compressibility (mean r=0.34, 95% CI = 0.16-0.52), suggesting that more redundant images may have an early processing advantage, and that early visual processing may employ redundancy reduction.

Acknowledgements: National Science Foundation grant (1736394) to MRG and BCH.

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Semantic, statistical and aesthetic determinants of how natural and urban images make us feel

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Introduction: Natural environments are consistently more preferred and perceived as more restorative than urban environments. Studies have shown that certain high-level semantic characteristics of natural environments (presence of water and green vegetation), low-level image properties (color, edge density, spectral slope, entropy) and perceived aesthetics are all associated with increased ratings of preference and perceived restorativeness. However, these factors have been studied in isolation of each other with their relative contribution in driving the perception of natural and urban images still unknown. Method: We investigate how the perceived restorative properties of natural (N=200) and urban (N=152) images are influenced by a variety of semantic subcategories (Water, Greenery, Street, Building or Architecture) and the associated low-level physical properties including chromatic (HSV) and spatial characteristics (amplitude spectrum slope, fractal dimension, entropy, edge density, and directionality). The images were rated for perceived complexity, beauty, liking and visual interest. To assess perceived restorativeness we asked participants to report how engaged, calm, and refreshed the images make them feel. In experiment 1, a total 638 participants (Amazon MTurk) viewed and rated natural (N=318) and urban scenes (N=320) separately on one of the seven rating scales with at least 42 participants per rating scale. In experiment 2, additional 362 participants (UNSW SONA Participant Pool) rated all natural and urban scenes on one of the rating scales with at least 40 participants per rating scale. Results and Conclusions: We found large and significant differences in the low-level physical properties not only between natural and urban scene categories but between the semantic subcategories of each scene type. While image category (natural vs urban) and the respective semantic sub-categories were strong predictors of perceived aesthetic and restorative properties, partial correlation and regression analyses, showed that low-level image properties were independent predictors of both perceived aesthetic and restorative properties.

Acknowledgements: Australian Research Council (ARC) Discovery Project Grant DP170104018

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Through the looking-glass: Visual sensitivity to chirality

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If you woke up in Wonderland, could you tell? Wonderland, of course, is the mirror-reversed world discovered by Alice in Lewis Carroll's 1871 novel, "Through the Looking-Glass" — and so our question here is whether naive observers are sensitive to patterns that distinguish images from their mirror-reversals. Many patterns in the natural world are "chiral", such that their mirror images are not superimposable. In a series of large online studies (collecting nearly 100,000 judgments), participants were shown a flipped version and an original version of a natural image, and simply had to guess which was which with no other information. (No legible writing was present in the images.) Results revealed a striking sensitivity to chirality; participants were able to identify which image was flipped and which was normal at rates significantly above-chance, even without any obviously distinguishing features. In Experiment 1, we showed participants images from a large database of social media photos. We observed above-chance performance not only in average accuracy across participants, but also on the image-level: Over 80% of the 500 different images had above-chance performance. Experiment 2 revealed that this chiral sensitivity pervaded the space of natural images and was not specific to any one image class: When we showed participants images from published databases of objects, natural scenes, artificial scenes, and faces, we again observed above-chance performance. Taken together, our results show that humans can not only identify visual chirality but also generalize it across different types of images. Chirality plays a role in a wide variety of natural processes, including the growth of seashells, the organization of chemical structures, and even the handedness of bimanual species. Our work here suggests that chirality arises not only in the world around us but also in human visual processing.

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Deep-net-derived surface estimations from natural scenes predict voxel responses in scene-selective cortex

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Our world is full of diverse types of visual information, yet visual attention and memory experiments focus almost exclusively on understanding attention/memory of basic visual features and discrete objects, in part because our understanding of how people represent scene surface information cognitively and neurally is very limited. Recent work (e.g., Lescroart & Gallant, 2019) has made headway in quantifying such surface representations, finding 3D surface information in scene-selective cortex, yet their results were limited to artificially generated images for which ground-truth 3D information exists. Here, we use DNNs (Zamir et al., 2018) to estimate ground-truth distance and surface-direction information based only on RGB stimulus images in the publicly available BOLD5000 fMRI data set. This procedure yielded artifact-free distance and surface-direction estimates for 978 of the 1000 scene images in the BOLD5000 stimulus set. Using a similar encoding model to Lescroart & Gallant (2019), we found significant predictions of voxel responses in scene-selective cortex (occipital place area and parahippocampal place area: 3/3 participants significant; retrosplenial complex: 2-3/3 participants significant depending on hemisphere). These results lay the foundation for investigating scene surface processing in more naturalistic environments and tasks, a critical step towards understanding visual and cognitive processes in the real world.

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Different responses of the scene-selective cortical regions to magnocellular- and

parvocellular-biased visual information

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Scene perception relies on a set of cortical regions, such as the parahippocampal place area (PPA), retrosplenial complex (RSC), and occipital place area (OPA), exhibiting dissociable functional selectivity to various scene properties. Debates are ongoing about what specific types of visual information are represented in these regions to mediate their different functions. This fMRI study examined the neural bases of functional dissociations of scene-selective regions by selectively biasing visual inputs from the magnocellular (M) and parvocellular (P) cells and comparing patterns of their cortical projections. We manipulated 96 scene images to create stimuli that biased M- (low-contrast, achromatic images defined by luminance) or P- (defined by iso-luminant, red-green contrast) responses, adjusted for each participant's thresholds. Twenty-four participants performed indoor/outdoor categorization of M- or P-stimuli presented for 1 second. Participants were significantly faster at categorizing P-biased scenes than M-biased, interestingly contrasted to the M-advantages reported in fearful/neutral face categorization (Cushing et al., 2019). For fMRI data analyses, each participant's PPA, RSC, and OPA were functionally defined using a separate localizer scan. The PPA was significantly more responsive to P-stimuli in general, whereas the RSC showed greater responses to M-stimuli with a slight preference for outdoor images. The OPA activations did not show systematic M/P bias. We next tested whether the PPA and RSC preferences for P- and M-stimuli, respectively, were specific to the task of scene processing. In separate fMRI runs, participants viewed rapid flashes of an achromatic, low-spatial-frequency grating (M-biased) or slow alterations of a red-green, high-spatial-frequency grating (P-biased). Although the M-bias became weaker in the RSC, the P-bias of the PPA remained robust for the scene-irrelevant gratings. Our findings together demonstrate differential processing biases of the scene-selective regions for visual attributes conveyed from the retina to the cortex, facilitating the efficient perception of complementary scene properties.

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Context Matters: Recovering Human Visual and Semantic Knowledge from Machine Learning Analysis of Large-Scale Text Corpora

View Poster | Visit me in Gather.Town Manatee Room on Tuesday 3:00 pm - 5:00 pm EDT

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Applying machine learning algorithms to automatically infer relationships between concepts from large-scale collections of documents (embeddings) presents a unique opportunity to investigate at scale how human visual and semantic knowledge is organized, including how people judge fundamental relationships, such as similarity between concepts ('How similar are a cat and a bear?') and the features that describe them (e.g., size, furriness). However, efforts to date have shown a substantial discrepancy between algorithm predictions and human empirical judgments. Here, we introduce a novel approach of generating embeddings motivated by the psychological theory that semantic context plays a critical role in human judgments (i.e., the topic or domain being considered in the documents, such as descriptions of the natural world vs. writings about travel and transportation). Specifically, we train state-of-the-art machine learning algorithms to generate contextually-constrained embeddings using contextually-relevant text corpora (subsets of Wikipedia containing tens of millions of words). We show that by incorporating insights from human cognition into the training procedure of machine learning algorithms, we can greatly improve their ability to predict empirical visual and semantic similarity judgments and feature ratings of contextually-relevant concepts: our method exceeds 90% of maximum achievable performance in predicting similarity judgments, as well as the best performance to date in predicting feature ratings (e.g., size) for concrete real-world objects (e.g., 'bear'). Furthermore, our method outperforms models trained on billions of words, which suggests that qualitative, psychologically relevant factors may be as important as sheer data quantity in constructing training sets for use with machine learning methods of investigating cognitive phenomena. By improving the correspondence between representations derived automatically by machine learning methods (embeddings) and empirical measurements of human judgments, the approach we describe helps advance the use of large-scale text corpora to understand the structure of human visual and semantic knowledge.

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Attention: Capture 1

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Attentional Cueing in the World: Temporal and Spatiotemporal Cues for Road Hazards

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What attentional cues are most effective in complex, dynamic scenes, and how might cueing effects differ in real-world scenes and situations like driving? To test this, we had 100 online participants (all licensed drivers) detect dangerous events in videos of near-collisions across four cue conditions: no-cue (baseline), temporal (a bar at the bottom of the screen, localizing the hazard in time, but not in space), spatiotemporal-valid (a box indicating the time and location of a dangerous object in the scene) and spatiotemporal-invalid (a box indicating a distracting object simultaneous with hazard onset). On each trial, participants indicated whether the hazard was on the left or the right half of the display as quickly as possible following hazard onset. Relative to the no-cue baseline (542 ms, 87% correct), we found significantly faster RTs with spatiotemporal-valid (479 ms, $p=0.03$ vs. no-cue) and temporal (481 ms, $p=0.04$ vs no-cue) cues, and significantly slower responses with spatiotemporal-invalid cues (600 ms, $p<0.0001$, vs. no-cue). Hazard detection performance was not significantly different between no-cue (87%), temporal (85%) and spatiotemporal-valid (88%), but dropped significantly versus baseline in spatiotemporal-invalid (76%, $p<.0001$). In this real-world setting, attentional cueing shows similar effects to those observed in the lab, suggesting that they translate to time-critical settings in the world. Dangerous situations develop quickly on the road, and cueing drivers to them can buy them critical time needed to respond. Our results suggest that a simple cue that only temporally localizes a hazard may be more useful for drivers than a complex cue that localizes in time and space, because inaccurate spatiotemporal localization brings substantial RT and accuracy penalties (a +58 ms increase in RT, and a 12% reduction in accuracy). Our results extend attentional cueing into driving, and suggest how attention can be studied in real-world settings.

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Examining Overt and Covert Attentional Capture by Task Irrelevant Stimuli during a Novel Continuous Performance Task

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Paradigms used to examine attentional capture are limited by the presentation of stimuli that are not entirely task irrelevant. Moreover, attentional capture has rarely been studied in the context of continuous task performance. Consequently, it is not possible to measure the duration of the distractor interference effect while participants are continuously engaging in a task. These limitations represent important obstacles to existing paradigms as they do not reflect the type of entirely irrelevant, spontaneous distraction that occurs when individuals are continuously engaging in daily life tasks. To address these limitations, we implemented a new methodology based on a paradigm designed by Forster and Lavie (2011). Participants worked through a 12-item circular array making consecutive forced choice responses as to whether the identity of an item was a letter or a digit. On thirty percent of the trials, a distracting colorful cartoon character image was presented in the center of the circular display. Participants were instructed to respond as quickly and accurately as possible to the identity of the items until they had responded to the last item in the array. Moreover, we tracked the participants' eye movements throughout the entirety of the task. Response times (RTs) to the items immediately following the presentation of a distractor were significantly slower than RTs to items when no distractor was presented. Importantly, the distractor's effect on RTs was maintained over three responses following

distractor presentation, providing evidence for lasting attentional capture by entirely irrelevant distractors. Despite this prolonged interference effect, there was no evidence of overt oculomotor capture over these three responses, suggesting that distraction by entirely irrelevant distractors is covert. These findings are important as they provide further evidence for the ability of distractors presented with abrupt onsets to capture attention despite participants having no attentional set for these distractor stimuli.

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Linking Threat-Related Attentional Biases Toward Bicyclists to Driving Behavior

View Poster | Visit me in Gather.Town Dolphin Room on Tuesday 3:00 pm - 5:00 pm EDT

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Attention has consistently been shown to be biased toward threatening objects in experimental settings, leading to distraction in a goal-directed attention task. In real-world environments, automobile drivers perceive close encounters with bicyclists as threatening, permitting an examination of the implications of threat-related attentional biases with respect to real-world behavior. Here, we examined whether participants in a high-fidelity driving simulator perceived encounters with bicyclists as threatening and how this modulated driving behavior. Participants (n = 101) with a valid driver’s license and at least 1.5 years of driving experience completed two simulated drives, one with a 40 miles-per-hour (mph) posted speed limit and another with a 25 mph posted speed limit. Each drive consisted of four interactions with a bicyclist. For the first interaction, participants encountered a bicyclist riding inside the lane in front of their vehicle and were forced to decide when to overtake the bicyclist or to continue trailing behind the bicyclist. The other three interactions included a right turn, a left turn, and a stop at a 4-way intersection in which the participant and a bicyclist arrived at the intersection at approximately the same time, requiring the participant to decide whether to yield to the bicyclist. We hypothesized that bicyclists would evoke a robust threat and orienting response, the strength of which would be associated with safer driving behavior. The results revealed increased physiological responses of heart rate and electrodermal activity when the bicyclist is in the driver’s field of view. In addition, drivers made increased eye movements toward the bicyclist, which were collectively associated with safer driving (measured from distance between driver and bicyclist, decisions whether and when to pass a bicyclist, and consistency of lane position during bicyclist interaction). Our findings offer a real-world demonstration of how threat-related attentional biases can be adaptive.

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Measuring attentional capture across learned states of cognitive flexibility

View Poster | Visit me in Gather.Town Dolphin Room on Tuesday 3:00 pm - 5:00 pm EDT

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Individuals adapt their readiness to shift spatial attention or switch tasks, referred to as cognitive flexibility, according to changing environmental demands (Dreisbach & Haider, 2006; Sali et al., 2020). However, the domain-specificity of flexibility learning and the resulting implications for attentional capture are unknown. If cognitive flexibility learning is domain-specific, high switch-readiness should be unrelated to distractibility. Alternatively, learned task-switching flexibility may be associated with an increase in the likelihood of attentional capture, reflecting domain-independent learning. Across two experiments, we manipulated the likelihood of task switches across consecutive trials within visual search paradigms to test whether learned flexibility is associated with increased distractibility. In Experiment 1, participants completed an additional singleton paradigm, searching for the unique shape in each array, and in Experiment 2, participants completed a feature search paradigm, searching for a shape-defined target. In both experiments, a color singleton was present in half of the trials and participants periodically switched between two categorization rules. Experiment 2 also included rare probe trials in which participants reported letters that had briefly flashed at each location (as in Gaspelin et al., 2015) to test whether task-switching flexibility weakened singleton distractor suppression. In both studies, behavioral task-switching costs were smallest in blocks of trials with frequent trial-by-trial task-switching, indicating learned adjustments in cognitive flexibility. While participants were overall slower on distractor present trials than distractor absent trials in Experiment 1, there was no difference in the magnitude of

capture according to the likelihood of task-switching. In Experiment 2, response times did not differ between distractor present and distractor absent trials in the feature search task and we observed no difference in probe recall at the singleton distractor location according to switch likelihood. Together, our results suggest that flexibility learning in the domain of task-switching does not carry consequences for moment-by-moment distractibility.

Threatening Targets Unable to Capture Attention, Yet Won't Let It Go

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Previous research has provided evidence that an irrelevant, but threatening, object can capture visual attention compared to the absence of a threat (Hansen & Hansen, 1988; Öhman et al., 2001). This impact can be measured in an irrelevant singleton paradigm, in which the unrelated threatening object identity does not predict the target location during visual search (e.g., Theeuwes, 1991). Based on this paradigm, we expected participants to respond to threatening targets faster than neutral targets if attention capture was occurring based on the target's threat-status. However, our research has repeatedly found the opposite in that threatening targets result in longer search times. We hypothesized that threatening targets may result in oculomotor capture (search time), but the increase in response times may be explained by potential distraction or disengagement after the initial threatening target fixation (verification time). Participants searched and discriminated the left-right orientation for a red singleton. Vector representations were used for stimuli images; the threatening stimulus was a single spider and non-threat stimuli were butterfly images. The target having a threat-status occurred at chance based on the search display set sizes (4 or 8 items). We replicated our previous findings, where trials with a positive target threat-status were associated with an increase in response times. Assessing oculomotor behaviors, we found (a) no differences occurred in initial search time for targets based on threat-status, (b) an increased likelihood of fixating on a threating target compared to no threat target, and (c) threatening targets were associated with increased target verification times. Our results suggest the threatening information did not induce attentional or oculomotor capture, but supports our hypothesis that task irrelevant threatening items result in difficulty in disengaging or impairs decision-making in the primary search task.

Attentional Capture during Public Speaking in Virtual Reality Environment

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It is well established that allocation of gaze is tightly linked to behavioral goals, but many situations in the natural world are loosely structured, and many of the events are unpredictable. Increasing evidence suggests that attentional capture can be context-dependent and modulated by attentional control (Luck et al., 2020). Yet, we know little about this mechanism in unstructured situations and what events might be attentionally salient. This is relevant for social interactions, where the responses of other people may carry important information. To examine the role of attentional capture in a social context, we asked 84 participants to give a 5-minute speech in a virtual reality environment. A pre-recorded 360 deg film of 5 audience members was presented in an Oculus DKII headset with an SMI eye-tracker. Individual audience members were instructed to act either interested (e.g. leaning forward or nodding), not interested (e.g. looking away or using a cell phone), or neutral (e.g. shifting in the chair). We characterize the speakers' gaze in response to these audiences in terms of "capture" (allocated towards an audience member during an action) and "repulsion" (shifted from an audience member during an action). We found that audience actions reliably attracted gaze if they were in the field of view, a factor of four times more than when no actions were performed. Speakers also looked away from the audience member during an action (twice as likely compared with no-action baseline), although less probable than attraction. Interestingly, neither the size of the movement nor their indication of interest appears to have much effect. The results suggest that the speaker fixates on the audience member during an action in order to gain socially relevant information, and that the effectiveness of attentional capture mechanisms is strongly modulated by social relevance.

Acknowledgements: F31 NRSA to Mikael Rubin

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Oculomotor Feedback Rapidly Reduces Attentional Capture

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Prior research has demonstrated that people have limited awareness of their oculomotor movements during scene viewing and visual search. Furthermore, individuals have some awareness of when their attention is captured by a salient-but-irrelevant stimulus, but this awareness is limited and incomplete. The present study aimed to assess whether raising an individual's awareness of oculomotor capture could enhance their ability to resist such capture. We examined this using a novel near-real-time oculomotor feedback manipulation during a visual search task in which participants looked for a shape-defined target while trying to ignore physically salient color-singleton distractors. The search display consisted of six shapes, one of which was always different than the other five (a circle among diamonds, or vice-versa), which served as the target. On distractor-absent trials, all shapes were colored in either red or green. On distractor-present trials, one of the non-target shapes was colored differently from the other shapes, serving as a salient distractor. Half of the participants were instructed to saccade to the target and ignore the colored distractors. The other half of the participants were similarly instructed to ignore the distractors but were also informed that the computer would emit a tone if they looked at the distractor (auditory feedback condition). This auditory feedback provided immediate awareness to when attention had been captured. The results indicate that the frequency of oculomotor capture was significantly reduced in the feedback group compared to the no-feedback group, as was the cost in oculomotor response time attributable to the distractor for target-going saccades (a measure of covert attention). These findings demonstrate a causal link between feedback concerning oculomotor capture and the ability to resist such capture.

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Even Highly Salient Distractors Are Proactively Suppressed

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Do physically salient stimuli—such as color singletons—have an automatic power to capture attention? This question has spurred a longstanding debate, but recent evidence has supported a hybrid model called the signal suppression hypothesis. According to this account, salient distractors automatically attract attention, but can be proactively suppressed via top-down control processes to prevent attentional capture. Importantly, many of the previous studies supporting this account have used singleton distractors with relatively low salience. That is, most studies indicating suppression of salient stimuli have used color singletons at relatively low set sizes (4 or 6 items). The current study adapted the capture-probe paradigm to assess capture by highly salient color singletons at exceptionally large set sizes (10 or 30 items). In three experiments, we observed no evidence that highly salient color singletons captured attention and instead found they were suppressed. Importantly, we did find clear evidence that suppression effects can sometimes be masked by floor effects in overall probe performance. We introduce a new methodology to remedy this problem: limiting the number of items that are simultaneously probed. Altogether, the results support the signal suppression hypothesis and refute bottom-up accounts of attentional capture.

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Attentional capture by threat is independent of uni- versus multi-modal threat intensity

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Stimuli signalling reward capture attention even when non-salient and task-irrelevant. Such attentional bias is value-dependent, meaning that stimuli signalling higher reward induce greater capture. Stimuli signalling threat also capture

attention, but whether threat intensity modulates the magnitude of attentional capture by associated stimuli remains unclear. We manipulated threat intensity using electric shocks, loud white noise and a combination of both to address this question. Doing so also allowed us to examine whether multisensory integration potentiates attentional bias. Indeed, threat perception in real life is a multisensory experience – for example, sight of a predator may be accompanied by a growling sound – and such integrative threat signals are known to modulate attentional capture. In a training phase, participants generated a speeded saccade to a square, the colour of which signalled either an electric shock, loud white noise, the two outcomes combined, or no outcome. In a test phase, a square (distractor) and a circle (target) were presented simultaneously; the same colours were used as during training, fully crossed and counterbalanced with respect to target and distractor status. Participants were tasked with making a speeded saccade to the circle. We found that test phase RTs were slower when there was a threat-signalling distractor than when there was a threat-signalling target, indicative of attentional bias towards threatening stimuli. However, there was no difference in the magnitude of attentional bias between the three aversively conditioned stimuli, with Bayes factors supporting the null hypothesis. Interestingly, subjective ratings of perceived aversiveness indicated that the combined outcome was most aversive for a majority of participants. Together, these results suggest that threat-induced attentional bias is independent of threat intensity, and that although multisensory integration augments perceived aversiveness, it does not potentiate attentional bias to threatening stimuli.

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Semantic generalization of threat-related attentional capture

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This study aimed to determine whether attentional prioritization of visual stimuli associated with punishment transfers across conceptual knowledge independently of physical features. Participants performed a Stroop task in which eight words were presented individually. These words corresponded to four pairs of synonyms: clock-time, assist-help, fuel-gas, yolk-egg. The chosen pairs were all rated highly for frequency of free association when single word priming was provided. There was no phonological or orthographic similarity between either word of each pair. Words were presented in equiluminant red, green, blue, and purple. In the learning phase, the first word of two pairs (randomly selected and counterbalanced across participants) was associated with shock independently of performance (with a reinforcement ratio of 66.67%). The subsequent generalization phase was similar to the learning phase but no shock was delivered. Participants were instructed to manually report the ink color of each word as quickly and accurately as possible, ignoring their meaning. Before the learning phase, we specified that trials sometimes resulted in the delivery of a shock, but no information about stimulus-punishment contingencies was given. Results are consistent with semantic generalization of stimulus-punishment associations. Synonyms of words paired with shock produced a Stroop interference effect (i.e., slower response times) in the learning and the generalization phases, relative to synonyms of words not paired with shock, suggesting they were prioritized by attention (due to their semantic association with words related to shock) and so more difficult to inhibit.

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Exogenous attention improves perception through visual-cortical facilitation, not suppression

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It is unknown whether exogenous attention facilitates cortical processing of attended information, suppresses processing of unattended information, or some combination of the two. In order to test this, we recorded EEG while participants (N = 19) performed a cross-modal attentional cueing task that included peripheral auditory cues that oriented attention to the left and right side of space as well as central “no-shift” cues that did not trigger a spatial shift of attention. This allowed

us to apply a cost-benefit analysis to separate facilitatory from suppressive effects in behavioral performance as well as neural activity. Participants performed a visual discrimination task and reported the orientation of a tilted visual target that was presented briefly after the cues. Target discrimination accuracy following valid cues was higher than following invalid cues as well as central no-shift cues ($ps < 0.003$), consistent with behavioral benefits at the attended location and no costs at the unattended location. Mirroring this behavioral pattern, peripheral cues elicited a greater positive deflection in the EEG signal over visual cortex contralateral vs. ipsilateral to the cued side ($p < 0.001$), and the contralateral waveform differed reliably from the waveform elicited by the central no-shift cues ($p < 0.001$) with no difference between the central and the ipsilateral waveforms ($p = 0.46$). This suggests that visual-cortical processing was boosted at the attended location, with no signs of suppression at the unattended location relative to baseline. Furthermore, we observed a sustained bilateral positivity at frontal sites following peripheral vs. central cues ($ps < .001$) that represents a novel index of exogenous spatial attention. Overall, our data demonstrate that the exogenous orienting of spatial attention results in visual-cortical enhancement at the location of a salient cue but does not result in spatially specific suppression of visual processing at uncued locations.

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Learned but not distracting: low-value stimuli and value-driven attentional capture

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Stimuli previously associated with reward slow response times (RTs) when presented as irrelevant distractors in subsequent, unrewarded tasks (value driven attentional capture, VDAC). Typical VDAC training requires search for one of two experimentally-determined, colored circles and an orientation judgement of a line inside the color-defined target. Reward follows correct responses, associating high- or low-value with specific colors. Distractors rendered in high-value colors consistently slow RTs in an unrewarded test phase, an outcome that is rarely observed for low-value colors. Might this be due to a failure to adequately learn the reward contingencies during training? 22 observers underwent a modified training phase. On each trial, two objects were presented. Each object was comprised of distinct features: color, shape, and internal line orientation. Participants chose one object and received high, low, or no reward. Only four colors appeared and two were consistently paired (high- or low-value and a no-value match). The task was to maximize earnings by learning which specific feature predicted reward. Training was followed by the standard VDAC test phase. During training, each value stimulus was chosen significantly more often than its no-value match, confirming learning for both high- and low-value colors. However, only high-value colors engendered VDAC during test, as is typical. Using maximum likelihood estimation, individual RT distributions were fit with a three parameter, exponentially modified Gaussian function and the condition means of the resultant distributions were compared, converging with results from model-free analyses. Stimuli associated with low reward consistently fail to generate VDAC. Our results rule out the possibility that this is due to a failure to learn, as participants developed clear preferences for both low- and high-value colors during training. More research is needed to explain how reward learning interacts with other aspects of cognition to produce robust capture effects.

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Latent attentional capture is dependent on search display duration

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While research from additional singleton paradigms suggest that a uniquely transient visual stimulus reliably captures visuospatial attention, research from contingent capture paradigms suggest capture by such a stimulus occurs only when it shares features of the target. Gaspelin, Ruthruff, and Lien (2016) proposed a solution to this discrepancy: attentional capture by a uniquely transient visual stimulus may be latent in contingent capture paradigms when the target in the subsequent search array is easily distinguished from distractors. That is, capture effects are not seen when attention does not need to dwell for long on the onset cue location to reject distractors because they are easily distinguishable from the target. Capture effects are revealed, however, in difficult visual search tasks because attention must dwell on the onset cue location because of high target-distractor similarity. It remains unclear why attention capture

effects from an abrupt onset have been reliably observed in cueing studies, regardless of whether visual distractors are included in the target display. To examine this, our first experiment embedded a distractor-less search condition into an otherwise standard contingent capture paradigm to evaluate whether latent capture could also be revealed by merely removing the distractors. Consistent with the attentional dwelling account, we found latent cueing effects in the distractor-less condition. Our second experiment was identical to the first except the search array duration was extended from 120 ms to until response, as is typical of more traditional Posner cueing paradigms that show capture from a uniquely transient visual stimulus. This experiment revealed similar capture effects across all levels of search difficulty, consistent with more traditional Posner cueing paradigms but inconsistent with Gaspelin et al (2016). The results suggest that attentional capture from cues that do not share features with targets can be moderated by target display duration.

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Learned Associations Among Objects Bias Attention

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A growing body of evidence suggests that semantic knowledge can influence the guidance of attention. For example, when observers search for a particular object, their attention is often biased toward semantically related objects in the display. In the present study, we assessed whether learned associations among objects can similarly bias attention. Participants searched for one of four targets among pairs of novel shapes. During an initial training phase, each target always co-occurred with an associated distractor in a fixed spatial configuration. During a subsequent test phase, each target appeared equally often with the associated distractor or a different distractor. The target and distractor could also be presented in the same pair or different pairs during this phase. In our first experiment, the target and distractor were presented in the same pair during the test phase. In this case, participants were faster to detect the target when the associated distractor was present. However, while participants were slower to respond on target-absent trials, they were not slower to respond when the associated distractor was present. This suggests that attention was biased toward the associated distractor, but only when it appeared at the same location as the target. In a second experiment, the target and distractor were presented in different pairs during the test phase. In this case, participants were slower to detect the target when the associated distractor was present. Participants were also slower to respond on target-absent trials, and were even slower to respond when the associated distractor was present. This suggests that attention was biased toward the associated distractor, even when it no longer predicted the location of the target. Together, these findings indicate that learned associations among objects can bias attention, and suggest that statistical learning may contribute to the effects of semantic relationships on attention.

Spatial Vision: Psychophysics 1

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A line-doubling illusion

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We present a novel ‘dazzle’ illusion in which a bar has the reverse polarity of the oblique square-wave grating on which it lies. When this bar is viewed in near peripheral vision, it can look doubled, as if there were two bars side by side and touching. During direct fixation the bar is seen veridically. But in near peripheral vision, say when one looks at the edge of the background, the bar looks doubled, like two bars side by a side, touching each other making three vertical edges (the middle one shared by the two bars). We examined two possible factors that could contribute to the effect – blurring and phase insensitivity of the periphery – but found that they played no role. We also asked whether it was contrast reversal or phase shift cause the line doubling. In the square wave grating, this contrast reversal that defines the bar is also a 180° phase shift relative to the background grating. To separate the two, we used pin-striped and ramp gratings where a 180° phase shift is quite different from a contrast reversal. In both cases, when the bar is phase shifted it appears doubled, but when it is contrast reversed it does not. We conclude that spatial phase reversal, not contrast reversal, is responsible for perceptual doubling.

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Adaptation to medical images within and across imaging modalities

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Radiologists spend prolonged periods inspecting and interpreting medical images, and thus may adapt to the images as they are scanning them. In previous work we examined potential adaptation effects in the context of images acquired from full-field digital mammography (FFDM), and showed that these images can induce a variety of visual aftereffects including changes in contrast sensitivity and perceived texture (Kompaniez et al. 2013, 2018). Screenings are increasingly utilizing digital breast tomosynthesis (DBT), which unlike FFDM uses 3D imaging to produce multiple images at different depth planes, providing improved diagnosis. Images from the two modalities have textural differences and during a screening both may present and visually compared. We examined whether similar patterns of textural aftereffects occur across the different imaging modalities and also tested for transfer of adaptation between them. Stimuli were sections from FFDM and DBT (single plane) images of the same normal tissue that had BIRADS classifications of dense or fatty. Observers (non-radiologists) adapted to pairs of images from one category and then judged the perceived texture of image composites formed by averaging across categories. During adaptation images were rotated or mirrored at 200 ms intervals to reduce local light adaptation. Adaptation to dense images caused blends to appear more fatty and vice versa, and these effects occurred for both modalities. Adaptation to an image of the same tissue from one modality also biased the appearance of the tissue imaged with the other modality, though these effects were weaker when images from the two modalities were more similar. Similar interactions were also observed in a spatial analog of the adaptation, such that image blends tended to appear less like the images they were surrounded by. Our results suggest that both temporal and spatial contrasts could influence visual judgments within and across these different medical imaging platforms.

Acknowledgements: CA-237827

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Estimating perceptual priors with finite experiments

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Perception can be conceptualized as a process of unconscious inference, in which people combine sensory input with beliefs gleaned from past experience. Understanding the form, function, and neural representation of these beliefs, commonly called priors, is key to understanding how we perceive the world. To characterize priors, researchers can fit Bayesian ideal observer models to response data from perceptual experiments. The success of this strategy, however, is limited by the type and quantity of responses that can reasonably be measured and by the approach used for modeling the prior. Here, we systematically study these issues in simulated observers to understand the strengths and weaknesses in existing approaches, and to optimize future experiments for characterizing priors. We focus on a psychophysical experiment used to characterize priors about visual motion. We generated a set of observers with known priors that were all biased towards slow speeds, but varied in shape. We simulated a two-alternative forced choice task in which the observers determined the faster of two moving stimuli with variable speed and contrast. We then used two well-known approaches to recover an estimate of the prior from the simulated data. The first approach assumes that the prior is Gaussian with zero mean and unknown variance. This approach is computationally efficient, but makes strong assumptions about the shape of the prior, which limit the ability to fit other shapes. A second approach approximates the log of the prior as a piecewise linear function. While this approach is more flexible, we show that it can lead to shape

estimates that are systematically biased. For both methods, we determined the requisite number of trials to reliably differentiate two priors with a given level of shape similarity. These results suggest experimental design and analysis improvements that can strengthen our inquiry into perceptual priors.

Acknowledgements: This project was funded by the NIH (F32 EY032321 & T32 EY007043)

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FInD - Foraging Interactive D-prime, a rapid and easy general method for visual function measurement

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Comprehensive visual function assessment is a critical stage of basic (screening, inclusion/exclusion) and clinical (diagnosis, monitoring) science, but requires tests that can be frustrating, esoteric and prohibitively long, which can lead to inaccurate or incomplete testing. We introduce FInD (Foraging Interactive D-prime), a general-purpose method that rapidly and easily measures threshold functions. Subjects search a series of (typically 3) grids composed of (typically 4*4) cells. A random number of the cells contain targets of signal intensities ranging from difficult (d'=0.1) to easy (d'=4.5), thus a clear exemplar is always present. In a self-administered test that requires little or no explanation and is suitable for special populations, observers click or touch cells containing a target. The response in each cell is classified as a Hit, Miss, False Alarm or Correct Rejection, to calculate d' as a function of signal intensity, which is then fit with a decision function. The signal range in each grid is determined from the posterior estimates of slope and threshold (d'=1) from previous grids (or experimenter estimate on grid #1) to maximize the efficiency of the test (typically over 3*4*4=48 trials). We measured contrast sensitivity functions (CSF), threshold versus contrast functions (TvC) stereoacuity, spatial coherence and motion coherence thresholds in up to 14 normally-sighted observers with FInD and with standard temporal 2 Alternative-Forced-Choice (AFC) paradigms. Threshold and function parameter estimates for CSF and TvC were not significantly different for FInD and 2AFC paradigms, but took significantly less time (36.99+7.0s vs146.30±14.86s, p<0.01) to measure. Bland-Altman analyses showed no significant bias or test-retest differences for FInD. FInD solves multiple screening problems for comprehensive vision assessment and rapidly delivers accurate and precise estimates of multiple visual functions in an easy-to-learn, self-administrable, general paradigm.

Acknowledgements: Supported by NIH R01EY029713

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The orientation-difference cue in figure-ground separation: border ownership and timing

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Figure-ground separation, a crucial component of visual processing, can be driven by differences in contrast, orientation, and other local cues. We previously showed (VSS 2020) that the orientation cue has distinctive characteristics: figure-ground separation depends not only on the magnitude of the orientation difference, but also on whether the oriented component is present in the figure vs. the ground. Here we show that this dependence is invariant with respect to convexity vs. concavity of the figure, and determine how it evolves over time. In a 2-AFC task, subjects (N=3) distinguished a target image containing five randomly-positioned figures rendered by one synthetic texture superimposed on a background defined by a second synthetic texture, from a non-target image consisting of a uniform texture whose image statistics matched the spatial average of the target's statistics. Target and non-target images consisted of 64 x 64 arrays of 10-min black and white checks, and the figures covered 25% of the target's area. Texture construction enabled control of the spatial frequency content of figure and ground in one or two orientations. For figures consisting of circular discs, figure-ground separation was facilitated when the figure texture was oriented, compared to when the ground was oriented. This difference was linked to the degree of anisotropy, as determined from the textures' spectra (r=0.82, p<0.001). When figure boundaries were changed from convex to concave, results were similar, indicating that figure content and border ownership, but not border shape, determined performance. In preliminary

results (N=1), we find that this asymmetry develops slowly; it is largely absent for a presentation time of 125 ms but close to maximal at 250 ms. In sum, figure-ground separation uses orientation differences in a way that depends on figure-ground assignment, suggesting a recurrent process that evolves over time.

Acknowledgements: NIH EY07977

Poster Session H > Spatial Vision: Psychophysics 1 > Poster H100

Systematic deviations between human and ideal observers in visual spatial averaging imply adaptation to natural-image statistics

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Systematic errors in laboratory psychophysics tasks can reveal sophisticated perceptual mechanisms optimized for natural-image statistics. Here, we report an examination of the human ability to average spatially varying signals in two visual domains: brightness and stereoscopic depth. The spatially varying signals were presented with nine horizontal bars stacked vertically in a one-degree area centered on the fovea. Human observers discriminated the sign of the average brightness or depth. Previously, we reported that human behavior departs notably from ideal-observer behavior in these simple spatial averaging tasks. Additionally, with identical stimuli, human errors were partly systematic and repeatable. In the current study, we show that nonlinear encoding of individual feature values prior to averaging contributes to the systematic deviation between human and ideal performance. In both brightness and depth tasks, the estimated nonlinearity was compressive across observers. By simulating the fitted models, we found that models with compressive encoding yield better discrimination thresholds than equivalent models with linear encoding when: i) additive late noise corrupted averaging and ii) feature values had small spatial variability. In models of many perceptual tasks, the addition of late noise is common. In natural images, the sample variance of luminance or binocular disparity within a local patch is biased toward small values. Indeed, simulations of the fitted models show that compressive encoding mitigates the performance drop caused by the late noise. Critically, this performance mitigation was more pronounced when the spatial variability of feature values skewed toward zero, as seen in natural images. Therefore, the systematic deviation between human and ideal observers in our laboratory averaging tasks may, at least in part, reflect the visual system's adaptation to natural-image statistics in the presence of late noise.

Acknowledgements: This work was supported NIH grant R01-EY028571 from the National Eye Institute & the Office of Behavioral and Social Science Research

Poster Session H > Spatial Vision: Psychophysics 1 > Poster H101

Assessment of contrast sensitivity in children with Phenylketonuria

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Phenylketonuria (PKU) is a genetic disorder characterized by impaired ability to metabolize the amino acid phenylalanine (Phe) into tyrosine (Tyr), a precursor to neurotransmitters including dopamine. Dopamine deficiency is proposed to underlie cognitive deficits and reduced contrast sensitivity in PKU. However, consensus has not been reached on the spatial frequencies impacted. Conflicting results may be due to use of a chart-based contrast sensitivity test with poor test-retest reliability or to inclusion of participants with varied blood levels of Phe/Tyr. To assess these possibilities, we used a more rigorous, computer-generated psychophysical test to measure contrast sensitivity in 14 children with PKU (M age = 11.6 years), who had been treated with a phenylalanine-restrictive diet from an early age, and 81 age-matched controls (M age = 11.9 years). Seven children also received sapropterin dihydrochloride (Kuvan®; a drug that may decrease Phe) at some point during the study. Contrast sensitivity was measured with a four-alternative forced-choice orientation discrimination task (Freiburg Visual Acuity Test) at five spatial frequencies (1.5 - 18.0 cpd). A subset of children (9 PKU; 10 control) returned for repeat assessments; four children were receiving Kuvan. Phe/Tyr levels were measured in children with PKU before each assessment. The PKU group (before Kuvan treatment) showed significantly lower contrast sensitivity (47%) at 1.5 cpd compared to controls; no group differences were found at higher

spatial frequencies. Kuvan-treated children showed a reduction in Phe/Tyr, and a resolution of the contrast sensitivity deficit. The deficit persisted in children treated with diet alone, although a small improvement was noted. The contrast sensitivity deficit at low spatial frequencies in PKU is consistent with some previous studies, but the lack of deficit at higher spatial frequencies is not. This deficit is dependent on blood levels of Phe/Tyr, and possibly on the choice of contrast sensitivity test.

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Luminance modulations from eye movements predict visual sensitivity

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Several recent studies support the proposal that the visual system uses luminance modulations from eye movements to encode spatial information in the temporal domain. his proposal makes specific quantitative predictions about the ependence of visual sensitivity on the characteristics of the visual flow delivered by eye movements to the retina. Hre w tested these predictions by measuring contrast sensitivity in human observers, while manipulating the visual input via g ze-contingent display control. Subjects (N=7) reported the orientation (±45 deg) of 16 cycles/deg gratings, while e posed to retinal image motions replicating the signals delivered by fixational eye drifts with different amplitudes. As p edicted, sensitivity was directly proportional to the spatiotemporal power of the luminance flow released by eye m ovements at nonzero temporal frequencies. This is particularly striking given the complex, non-monotonic relation between drift amplitude and the power of luminance modulations. We then examined whether active changes in ocular drift affect sensitivity. Here subjects (N=5) were exposed to normal retinal image motion, and performance compared in the naturally occurring trials in which ocular drift was larger and smaller than average. We measured contrast sensitivity at two spatial frequencies that bear contrasting predictions (1 and 10 cycles/deg). A Brownian motion model of eye drift predicts that, as the amount of drift increases, the luminance flow contains more power at low spatial frequencies and less power at high spatial frequencies. In keeping with this prediction, trials with larger drifts were associated with better performance at 1 cycle/deg and worse performance at 10 cycles/deg. These results provide strong support to a theory of active space-time encoding. They show that oculomotor-induced luminance modulations drive visual sensitivity. They also raise the possibility that humans use eye movements to control the effective contrast of the stimulus on the retina.

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Perception and Action: Virtual environments 2

Poster Session H > Perception and Action: Virtual environments 2 > Poster H121

Influences of pedestrian group size on exit routes in an online desktop virtual environment

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Recent research indicated a general bias to follow a faster pedestrian in a simple egress task in both a real-world and an immersive virtual environment. Here, we extend previous work to investigate open questions regarding group size. In particular, do participants choose to follow faster or smaller groups? Two online experiments were conducted using the same general setup in which participants (N = 60 each) viewed two sets of virtual pedestrians walking towards a pair of doors on each side of the room. Participants were required to select one of the two doors via key press and were cued to respond when pedestrians had exited the room. Experiment 1 presented same-sized groups exiting of one two, three, or four pedestrians per side. These group sizes were selected to validate previous research using pairs of pedestrians and extend to larger groups. One group exited at one of three speeds (1.0m/s, 1.5m/s, or 2.0m/s), and the other group walked towards the opposing door at a constant speed of 1.5m/s, then the groups switched sides. This yielded six total

trials per group size for a total of 24 randomly presented trials. Results were similar to previous in-person real world and immersive VR studies indicating a general bias to follow a faster groups; however, the increase in group size decreased the likelihood to choose the faster group. This effect may be attributable to attentional demands or a noisier stimulus. Experiment 2 presented both symmetrical and asymmetrical group sizes walking at the constant speed (1.5m/s). Results indicated that participants chose to follow smaller groups especially when the number of pedestrians increased above one. These results help to characterize the social influences on pedestrian egress behavior. Ongoing work examines interactions between speed and group size.

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Poster Session H > Perception and Action: Virtual environments 2 > Poster H123

Perception of action-relevant egocentric distance is not underestimated in virtual reality

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In the past few decades, advances in virtual reality technologies have led to an explosion of investigations into visual perception. While each new generation of VR systems brings improvements in optics and graphical fidelity, an open question remains: To what degree, and under what circumstances, will visual perception in the real-world correspond to visual perception in the virtual world? The well documented phenomenon of the compression of egocentric distance perception in VR suggests that such correspondence may depend on factors such as graphical fidelity, presence, and the like (Armbrüster et al., 2008). We investigated whether real-world egocentric distance perception would correspond to virtual egocentric distance perception in two experiments. Participants were asked to make affordance judgments about the reachability of a real (Experiment 1) or virtual (Experiment 2) ping pong ball that rested on a real or virtual table, respectively. Participants in both experiments exhibited perceptual boundaries occurring at distances approximately equal to 118% of their physical reaching capabilities. This suggests that, while participants generally overestimated the boundary of their reach, there were no significant differences between the degrees to which this occurred in both types of environments. This underestimation of distance (or overestimation of reach) comports with another well documented phenomenon that suggests people generally overestimate their reaching capabilities by about 20% (Carello et al., 1989; Weast & Proffitt, 2018). The importance of these findings rests in the fact that virtual reality is increasingly being used in psychological, visual, and health related research as well as for different types of neuro-training and therapy. Taken together, these results provide empirical evidence of the close correspondence of perceptual boundaries across the real world and virtual reality.

Poster Session H > Perception and Action: Virtual environments 2 > Poster H124

Removing feedforward visual information affects performance but not learning in a sequence learning online task

View Poster | Visit me in Gather.Town Egret Room on Tuesday 3:00 pm - 5:00 pm EDT

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Visual information is critical for learning motor skills. The visual information can be split into feedback (fixations which provide motor execution results) and feedforward (fixations which plan for future actions) information. How feedback and feedforward visual information informs the motor learning process remains unknown. To investigate this question, we examined how the absence of feedback or feedforward visual information effected motor learning. Participants completed an online “video game” during which small objects traveled downward through 1 of 4 vertical channels at a constant velocity (Traveling the length of the channel in 1.3 seconds). Participants pressed the corresponding key(s) while the object(s) crossed the targets at the bottom of the vertical channels. Participants completed 8 trial blocks (practice, baseline, 5 training blocks and a post test). During each training block and the post test a fixed 10-object spatiotemporal sequence was repeated 15 times. Participants were divided into 3 groups for the training blocks: a

feedback-only group had only the bottom 40% of the channel visible, a feedforward-only group had only the upper 60% of the channel visible, and a full-vision control group. We hypothesized that the feedback-only group would match the full vision group in the beginning, but plateau due to the lack of feedforward information, while the feedforward-only group would initially improve slowly, but perform similarly to the full-vision group during post testing. Preliminary results partly support our hypotheses. In the first training block, the feedback-only group did perform similarly to the full-vision group while the feedforward-only group performed worse. However, at the post test, the two limited vision groups tended to perform better than the full vision group. The preliminary results suggest that limiting visual information during training may improve motor learning, perhaps by forcing participants to maintain a narrower focus of attention.

Perception and Action: Reaching, pointing and grasping 2

Poster Session H > Perception and Action: Reaching, pointing and grasping 2 > Poster H125

Attentional context-dependent memory during gradual visuomotor adaptation

View Poster | Play Video | Visit me in Gather.Town Egret Room on Tuesday 3:00 pm - 5:00 pm EDT

Joshua Liddy[1], Hee Yeon Im[1,2], Joo-Hyun Song[1]; [1]Brown University, [2]University of British Columbia

We recently demonstrated that the success of motor memory retrieval depends on whether participants consistently performed a secondary task during visuomotor adaptation and later recall, which was independent of available attentional resources (Song and Bédard, 2015). To date, the reinstatement of attentional context in visuomotor memory retrieval has been established only when a large visuomotor rotation (e.g., 45º) is introduced abruptly, which presumably triggers explicit awareness of the sensorimotor disturbance. Two remaining questions are 1) whether a gradually induced external perturbation also facilitates attentional context-dependent memory formation and, if so, 2) whether there is a critical temporal window for encoding the attentional state into visuomotor memory. To address these questions, we employed a gradual visuomotor rotation (from 0º to 45º) of cursor movement relative to hand movement on each trial during adaptation. In Experiment 1, we combined the gradual visuomotor adaptation task with an attention-demanding secondary task. We observed that visuomotor adaptation acquired under attentional distraction was relearned better under attentional distraction at recall. This result provides support that the formation of attentional context-dependent memory can occur even when the sensorimotor perturbation is gradually introduced. In Experiment 2, we examined whether the magnitude of motor errors determines the critical window for integration between attentional context and visuomotor memory since motor errors increased throughout the adaptation stage. We manipulated whether participants performed the secondary task concurrently in the early or late phase of visuomotor adaptation and whether they performed the secondary task at recall to match the attentional state to the early or late learning phase. We observed no difference in recall performance across early versus late learning phase groups. Further investigation will clarify whether this result is attributable to a flexible time window for attentional state encoding or a failure to integrate attentional context during visuomotor memory formation.

Poster Session H > Perception and Action: Reaching, pointing and grasping 2 > Poster H126

Unaltered motion-induced blindness in peri-hand space

View Poster | Visit me in Gather.Town Egret Room on Tuesday 3:00 pm - 5:00 pm EDT

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Research has shown that hand proximity affects visual experience in various ways, such as prolonging visual search, delaying switches between global and local elements, and biasing attention to stimuli presented near the hand. The present study investigated how hand proximity affects motion-induced blindness (MIB), a visual illusion wherein salient objects fluctuate into and out of conscious awareness when superimposed on a global moving pattern. On each trial, participants (N = 30, right-handed) viewed a display containing a central fixation, a static target, and a grid of blue crosses rotating clockwise. The target was a yellow ring positioned in the upper left or right quadrant of the display. Participants maintained gaze on the fixation while paying covert attention to the target. They pressed and held the space bar when the target disappeared from awareness, and released it when the target reappeared. The time between the space bar press and release was measured as the MIB duration. Participants were also instructed to respond with their

left or right hand while keeping the non-responding hand in the lap (i.e., hand-far) or on the same side of the screen (i.e., hand-near). The experiment was a 2 (responding hand: left, right) × 2 (non-responding hand position: lap, screen) × 2 (target location: left, right) factorial design with one block for each condition. The results showed a significant main effect of target location ($p = .043$), indicating that participants experienced longer MIB episodes when the target was presented in the upper left compared to the upper right quadrant. This is consistent with previous research showing that MIB is not uniformly distributed across space. Importantly, the results also showed that non-responding hand position had no effect on MIB duration, suggesting that the visual processing involved in MIB is less sensitive to hand proximity.

Acknowledgements: This work was supported by the SSC Summer Research Fellowships to HMS.

Poster Session H > Perception and Action: Reaching, pointing and grasping 2 > Poster H127

Dissociating mechanism underlying selection history bias for goal-directed reaching movements

View Poster | Play Video | Visit me in Gather.Town Egret Room on Tuesday 3:00 pm - 5:00 pm EDT

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Selection history has been known to influence behavioral performance independent of top-down-goals and bottom-up-saliency. However, the precise contribution of underlying processes like target facilitation and distractor inhibition for goal-directed reaching action is unclear. To address this, we used a reach-tracking and computational modelling approach. Participants reached an odd-colored target among three homogeneous distractors, while we recorded their continuous reach trajectory. Continuous trajectory provides a behavioral measure that captures the online dynamics between target and distractor competition as the target selection unfolds. To assess the relative contributions of target facilitation and distractor inhibition on reach target selection, in addition to conventional full-repetition (repeating target and distractor colors on subsequent trials) and full-swap conditions (swapping target and distractor colors on subsequent trials), we added the partial-repetition and partial-swap conditions. In the partial-repetition conditions, the target color remained unchanged, while the distractor was in new color, or vice versa; in the partial-swap conditions, target color was the distractor color of the preceding trial while distractor was in new color, or vice versa (Eimer et al., 2010). To evaluate target selection bias modulated by history, we compared the direction and the magnitude of reach curvature across conditions: a decreased reach curvature towards a distractor indicates facilitation of target selection. In accord with prior studies (Moher & Song, 2014), reach target selection was most facilitated in the full-repeat condition while most interrupted in the full-swap condition. We also observed that more increased reach curvature towards distractors in the partial-swap conditions than in the partial-repetition conditions. This result suggests that maintaining a feature in association with its role (as target or distractor) across trials is more beneficial for subsequent target selection. To quantify the dynamic interaction between target facilitation and distractor suppression, we are currently extending the neurologically inspired CoRLEGO (Choice-reaching-with-LEGO-arm-robot) model (Strauss et al., 2015).

Acknowledgements: This project is funded by NSF BCS 1849169 grant awarded to Dr. Joo-Hyun Song

Poster Session H > Perception and Action: Reaching, pointing and grasping 2 > Poster H128

Evaluating visuomotor coordination in children with amblyopia

View Poster | Play Video | Visit me in Gather.Town Egret Room on Tuesday 3:00 pm - 5:00 pm EDT

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Amblyopia is a visual developmental disorder characterized by poor visual acuity in one eye that cannot be immediately corrected with lenses. Amblyopia is associated with deficits attributed to vulnerability in the dorsal visual stream, including stereoscopic depth perception, motion perception, visuomotor coordination, and reading. Adults with amblyopia show deficits on reaching and grasping tasks, but less is known about visuomotor deficits in children, specifically, for complex tasks that require movement sequencing. Our aim was to assess hand-movement kinematics for a precision reaching and grasping task in children with amblyopia or strabismus. Visual acuity, stereoacuity, and fine motor coordination were assessed in 276 children ages 5-14 (21 with amblyopia or strabismus; 256 age-matched controls). A bead-threading task was conducted under binocular viewing and involved 30 trials of a sequence of 4 movements: reach-to-bead, grasp bead, reach-to-needle, thread onto needle. A Leap Motion tracker recorded hand movement. The main outcome measures were reach duration, peak velocity, acceleration and deceleration intervals of each movement, grasp and thread duration, as well as total movement time. The amblyopia group showed significantly longer durations than the control group on the grasp (z-score 0.77 vs. 0.00), thread (0.48 vs. -0.01), and total movement (0.56 vs. 0.00) parameters. Based on the maturation age for these parameters in the control children, the groups were then split into immature (ages 5-9) and mature groups (ages 10-14). Grasp duration was longer in both mature and immature amblyopia groups; thread and total movement durations were longer in the mature amblyopia group only. Stereoacuity, but not visual acuity, was significantly correlated with grasp, thread, acceleration and total movement durations for the full participant group. Grasp duration was the most disrupted kinematic parameter in children with amblyopia, regardless of age. Binocular vision rather than depth of amblyopia may determine the severity of visuomotor deficits.

Looking without seeing: Children do not distinguish efficient from inefficient means to achieve a goal

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Observing others is a powerful way to learn about goal-directed actions. But observational learning entails more than noticing the movement trajectory. It provides information about the actor's intended goal and the means to achieve it. Prior developmental work suggests that long before children can achieve goals themselves, they can detect others' goals. However, the question is still open as to whether young children notice efficient means to achieve a goal. Here, we addressed this question using a novel combination of methods (eye tracking, pupillary responses, EEG, and machine learning). Preschoolers (N=22) and adults (N=22) watched actors use efficient, adult-like and inefficient, child-like means of grasping a hammer to pound a peg. Our displays were designed to test whether children differentiate the efficiency of means to achieve a goal in a task where they do not use efficient means themselves. Eye tracking showed that participants at both ages looked equally long at the goal (peg), but differed in looking at the means: Adults looked longer at the hammer and hand and performed more gaze switches between hammer and hand and between hammer and peg; deep learning analysis distinguished efficient from inefficient grasps for adults, but not for children. Moreover, only adults showed differential physiological responses to efficient versus inefficient grasps with increased pupil dilation and differential patterns of action-related neural activity (EEG). Taken together, our findings show that children can actively direct their gaze to look at goal-directed actions without seeing whether the means are efficient or not. Moreover, findings suggest that the development of action perception is built from children's own motor experiences.

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Unilateral Cortical Resection of Both Visual Pathways Alters Action but not Perception in a Pediatric Patient with Pharmaco-resistant Epilepsy

View Poster | Play Video | Visit me in Gather.Town Egret Room on Tuesday 3:00 pm - 5:00 pm EDT

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Previous studies have found that pediatric patients with resections of the ventral visual pathway retain mostly normal visuoperceptual abilities. It is not clear whether visuomotor computations, carried out by the dorsal pathway, follow a similar behavioral pattern. We examined visuomotor and visuoperceptual behaviors in a pediatric patient TC, who underwent a cortical resection that includes portions of the left ventral and dorsal pathways. TC used her right and left hands to estimate perceptually the width of blocks that varied in width and length, and, in a separate condition, to grasp the same objects across their width. Consistent with previous studies, TC's perceptual performance was comparable to

that of controls. In contrast, TC had reduced visuomotor sensitivity to object shape but only when she grasped the objects with her contralesional right (and not ipsilesional left) hand. These results provide evidence for a striking difference in the reorganization profiles of the two visual pathways. This difference might be attributed to a greater degree of hemispheric specialization of the dorsal pathway, as well as to differential maturation rates of the two pathways, such that the dorsal pathway maturation precedes that of the ventral pathway.

Perception and Action: Affordances

Poster Session H > Perception and Action: Affordances > Poster H131

Visual perception of surface properties through direct manipulation

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As Gibson (1966) observed, vision is a component of a perceptual system whose function is to provide information in support of purposeful behavior. In this project we studied the perceptual system that supports the visual perception of surface properties through manipulation. In a series of trials, we gave observers the task of inspecting computer-graphics renderings of flat glossy surfaces and determining if there are any dents in the surfaces. The surfaces were displayed on a tangible display system (Ferwerda14), consisting of an Apple iPad running custom software that rendered the surface in the plane of the screen, and allowed observers to directly interact with the surface by tilting and rotating the device. On each trial we recorded how the observer manipulated the device/surface by storing the angular readings of the device's accelerometer. Like studies showing purposeful patterns of eye movements (Yarbus67, Ballard95), the results of our studies show purposeful patterns of manipulation that are diagnostic with respect to the task by producing images that reveal the locations of the surface dents. These studies suggest the presence of an active sensori-motor perceptual system involved in the perception of surface properties, and provide a novel method for its study using tangible display systems. We are currently developing a series of psychophysical experiments to determine the limits of the system in terms of shape and material discrimination, and to analyze how the dynamic visual patterns produced by the system are coded to provide information that supports the task (Dörscher13, Phillips15).

Poster Session H > Perception and Action: Affordances > Poster H132

Visual and Haptic Perception of Affordances of Feelies

View Poster | Visit me in Gather.Town Egret Room on Tuesday 3:00 pm - 5:00 pm EDT

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Most human-made objects are designed with a particular function and a particular user in mind. This means that most objects have well-defined affordances. An important question that remains unanswered concerns the perception of affordances of objects that were not created for a specific purpose. Investigating perception of affordances of such objects would provide insight into how affordances are perceived via exploratory activity. In addition, the comparison of perception of affordances of ambiguous objects across vision and haptics would offer a strong test of the lawfulness of information about affordances (i.e., the invariance of such information over transformation). The use of "feelies"— objects created by Gibson (1962) with no obvious function and unlike any common object— could shed light on these processes. The present study showed that when observers reported potential uses for feelies, modality significantly influenced what kind of affordances were perceived. Specifically, visual exploration resulted in more noun labels (e.g. "toy") and haptic exploration resulted in more verb labels (i.e. "throw"). These results suggested that overlapping, but distinct classes of action possibilities are readily perceivable using vision and haptics. Semantic network analyses revealed that visual exploration resulted in object-oriented responses focused on object identification, whereas haptic exploration resulted in action-oriented responses. Cluster analyses confirmed these results. Affordance labels produced in the visual condition were more consistent, used fewer descriptors, were less diverse, but were more novel than those in the haptic condition. How the unique shape of feelies influences affordance judgments is currently being investigated,

but the multiple convex and concave surface regions could be critical in providing information about affordances, with different patterns of surface curvature specifying different affordances.

Poster Session H > Perception and Action: Affordances > Poster H133

Object weight is visually available in simple kinematic features of object lifting actions

View Poster | Play Video | Visit me in Gather.Town Egret Room on Tuesday 3:00 pm - 5:00 pm EDT

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Imagine a friend hands you a plain cardboard box. You would probably want to know whether it contained bricks or feathers before trying to grab it. Understanding the physical properties of objects is critical in order to interact with the world effectively. Unfamiliar objects have latent properties, such as their weight, that are not directly observable. In previous work, we showed that observers can accurately determine which of two objects is heavier by seeing another person lift them. Furthermore, weight judgements were lifter-invariant – comparisons of objects lifted by two different people were just as accurate as comparisons of objects lifted by the same person. What visual cues support lifter-invariant weight perception? Candidate cues should be consistent across lifters without the need to be normalized to lifter-specific behaviors. Here, we sought to characterize kinematic features of object lifts and test which, if any, could be directly compared across different lifters to infer object weight. We filmed four individuals each lifting ten visually indistinguishable objects that ranged in weight from 100g – 2000g. In a series of behavioral experiments, we verified that: i) observers could precisely discriminate objects' weights after viewing lifts, ii) the precision of discrimination was lifter-invariant (not diminished when making comparisons across different lifters), and iii) performance was consistently good throughout the task, suggesting that cues were already known, not being learned on-the-fly. Next, we built models to discriminate object weights using annotated kinematic features from the videos: peak lifting and lowering speeds and overall lift durations. Comparing any one of these features to make trial-by-trial decisions about relative weight yielded performance on par with behavioral experiments and a close match to participants' responses. These results suggest that simple kinematic features are robust across different lifters and sufficient to account for observers' performance in weight lifting observation tasks.

Poster Session H > Perception and Action: Affordances > Poster H134

Factors affecting the perception of axis of rotation of pivot doors

View Poster | Visit me in Gather.Town Egret Room on Tuesday 3:00 pm - 5:00 pm EDT

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Doors afford the action of entry and exit from an enclosed space. Although doors usually swing about an axis of rotation which falls along one of its side edges, some types of doors like pivot doors, rotate about an intermediate pivot axis, with the surface of the door extending on both sides of the axis. The current study investigated the optical information available to detect the position of the axis of rotation of rectangular panels like doors. At the axis of rotation, the rate of change of optical angle subtended by texture elements, at the point of observation is zero. This information allows the observer to perceive the location of the axis. Participants indicated the location of the axis of rotation of a rotating panel in a virtual environment, viewed using a head mounted display, as quickly and accurately as possible. On each trial, the surface of the panel and its background had either no texture or had texture in the form of black dots. There were four texture conditions; (1) no texture on either the background or the panel, (2) texture on the panel but not on the background, (3) texture on the background but not on the panel, (4) texture on both the background and the panel. Also, the position of the axis of rotation, and the linear velocity of the edge farthest from the axis were varied. Results indicate that the presence of texture and higher velocity of rotation helps in the detection of the axis of rotation. Response time was faster, and accuracy was better when there was texture on the panel and the background, compared to no texture at all. The results suggest the importance of texture information and has implications in the design of doors and built environments.

Poster Session H > Perception and Action: Affordances > Poster H135

Integrating feedback to improve reaching estimates in virtual reality

View Poster | Play Video | Visit me in Gather.Town Egret Room on Tuesday 3:00 pm - 5:00 pm EDT

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Immersive virtual environments (IVEs) now allow for visual representations of a virtual body that have precise motion tracking for mimicking action. IVEs thus offer a powerful tool for studying visual perception and its relation to action capabilities and action calibration. Judgments of action capabilities in IVEs represent an objective measure for determining how closely a viewer's perception of space may match that of the real world. The current study evaluated judgments of reaching capabilities (both reaching up and reaching out) within an IVE. Our goal was to determine to what extent feedback from actual reaching improved participants' abilities to accurately make reachability judgments and if recalibration due to feedback differed across reaching behaviors. Participants completed alternating blocks of adjustment trials (perceptual estimations) and feedback trials. In adjustment trials, participants viewed an object starting close or far from reach and adjusted the location to where they believed they could just reach it. In feedback trials, participants viewed targets that were farther or closer than their actual reaching ability (blocks consisted of +-30%, +-20%, +-10%, and +-5% of the participants actual ability). They then decided whether the target was reachable and reached out to the target to receive visual feedback from a hand-held virtual controller. We found that for both reaching behaviors, reach was initially overestimated, and then perceptual estimations became more accurate as the feedback blocks progressed. Accuracy in the feedback trials was lower for targets just beyond reach (5%), suggesting that these targets were more difficult to judge correctly. This study establishes a straightforward methodology that can be used for calibration of actions in IVEs and has implications for applications that depend on accurate reaching within IVEs.

Perception and Action: Neural mechanisms 1

Poster Session H > Perception and Action: Neural mechanisms 1 > Poster H136

Influence of autistic tendencies on EEG correlates of body movement perception

View Poster | Visit me in Gather.Town Egret Room on Tuesday 3:00 pm - 5:00 pm EDT

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Growing evidence suggests that we understand others' mental states by internally recreating, or simulating, their external actions. For example, both executing and observing movement decreases the "mu" rhythm (8-14 Hz) over sensorimotor cortex in electroencephalography (EEG). Reduced mu suppression has been reported in autism spectrum disorder, a finding recently extended to neurotypical individuals with high autistic tendencies (Siqi-Liu et al., 2018). However, this study did not directly compare mu suppression for action execution versus observation, raising questions about the extent to which these effects reflect motor simulation per se. Furthermore, the influence of emotional content on mu suppression is relatively unclear: although emotional body movements are more attentionally salient, neutral movements may be more readily simulated due to familiarity and/or ease of execution. Here we directly compared mu suppression associated with motor execution and action observation as a function of autistic tendencies in a neurotypical sample (n = 37). Participants completed separate blocks of finger-tapping and observation of point-light displays (PLDs) of emotional and neutral body movements. Autistic tendencies were indexed by Autism Quotient scores (AQ; Baron-Cohen et al., 2001), and participants were grouped by median split. We found significant mu suppression over sensorimotor cortex for action execution (AE) and action observation (AO), regardless of AQ subgroup. However, whereas both groups showed highly significant correlations in the scalp distribution of mu suppression for AE vs. neutral AO, mu suppression of emotional AO was only significantly correlated with AE in the high AQ subgroup. Contrary to the idea that action simulation indexed by mu suppression contributes to emotion perception, these results suggest that accessibility of simulation is greater for neutral, as opposed to emotional, movements. Individuals higher in autistic tendencies show more consistent mu suppression for observation of both neutral and emotional movements, with potential consequences for perceiving others' emotions.

Acknowledgements: This work was supported by the National Science Foundation under Grant No. 1923178.

Poster Session H > Perception and Action: Neural mechanisms 1 > Poster H137

Prestimulus Alpha Phase Gates Afferent Visual Cortex Responses

View Poster | Play Video | Visit me in Gather.Town Egret Room on Tuesday 3:00 pm - 5:00 pm EDT

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Brain states prior to the presentations of physical stimuli shape the processing of the sensory input. It has been demonstrated that the amplitude and the phase of prestimulus alpha-band oscillation (7 -13 Hz), which are thought to have an inhibitory function, influence subsequent perceptual performance. Recently, prestimulus alpha power has been found to be negatively correlated with the amplitude of the C1 component of visual event-related potentials (ERP), which is thought to arise from afferent input onto the primary visual cortex. However, it remains unknown how the phase of prestimulus alpha is related to the C1 component. In current study, we reanalyzed the EEG dataset collected by Iemi et al. (2019) to investigate this question. In their experiment, participants (N = 25) were presented with a pair of task-irrelevant, high-contrast checkerboard wedges either in the upper (UVF) or lower (LVF) visual field with equal probability. These stimuli produced large amplitude C1 components which showed the typical polarity reversal with visual field location, suggestive of a calcarine source. We computed global field power (GFP) during the C1 time window, which is independent of the reference electrode. The trials were sorted based on the single-trial estimates of phase of prestimulus alpha and then the GFP amplitudes between phase levels were compared. Our results showed that, in both UVF and LVF, the GFP amplitude decreases with the phases deviating from the preferred phase angle at which GFP amplitudes were largest. Single-trial circular-linear associations between prestimulus phase and poststimulus GFP revealed significant effects restricted to the alpha frequency. These findings demonstrate that the phase of prestimulus alpha oscillations could modulate early stages of visual processing by gating the feedforward flow of sensory input between the thalamus and V1.

Poster Session H > Perception and Action: Neural mechanisms 1 > Poster H138

Spontaneous traveling waves are an intrinsic feature of ongoing cortical dynamics and regulate perceptual sensitivity

View Poster | Visit me in Gather.Town Egret Room on Tuesday 3:00 pm - 5:00 pm EDT

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Psychophysics has long focused on measuring the stimulus intensity that reaches the threshold for conscious report. However, variability in the neural activity evoked by the stimulus results in variable perceptual sensitivity for the same level of stimulus intensity. These variable fluctuations in neural activity have therefore been regarded as a source of noise, impairing the threshold for conscious perception estimated from signal detection theory. Recently we have found that variable fluctuations in cortical responses are due, in part, to the state of traveling waves of spontaneous cortical activity (Davis et al., Nature, 2020). These waves modulate stimulus-evoked spiking activity and perceptual sensitivity in marmosets trained to detect faint visual targets. Thus, in contrast to the traditional view of fluctuations as harmful noise, traveling waves improve perceptual thresholds. To gain insight into the mechanisms underlying traveling waves, we study a large-scale spiking network model with conductance-based synapses, biologically realistic topographic connectivity, and action potential propagation speeds consistent with those observed in unmyelinated horizontal fibers. We found that these properties were sufficient to generate spontaneous waves across the entire range of network parameters that produced asynchronous-irregular spiking dynamics (Brunel, J Comput Neurosci, 2000; Renart et al., Science, 2010). Further, we found that neuronal participation in these waves was sparse, enabling traveling waves to coexist with asynchronous-irregular spiking activity without necessarily inducing correlations, which have been found to impair perception (Nandy et al., eLife, 2019). This sparse-wave network regime remained sensitive to feed-forward input and modulated the strength of stimulus-evoked responses as observed in the cortex. This was in contrast to networks that produced dense spiking waves, which drove strong correlations and rendered the network insensitive to feed-forward input. Traveling waves appear to be an intrinsic feature of cortical dynamics, and they therefore likely impact the moment-to-moment processing of information throughout the brain.

Poster Session I

Attention: Capture 2

Poster Session I > Attention: Capture 2 > Poster I1

The Top-down Modulation of Task-Irrelevant Sounds Processing

View Poster | Visit me in Gather.Town Osprey Room on Wednesday 8:00 am - 10:00 am EDT

Shari Cavicchi[1], Andrea De Cesarei[1], Matteo Valsecchi[1], Maurizio Codispoti[1]; [1]University of Bologna

Loud noises are salient events that mandatorily call for attention. It was observed that, despite being irrelevant for the ongoing task, they receive sufficient processing resources to have their spatial dimension identified, as reflected by an enlarged positivity observed over the contralateral visual cortex (ACOP, Auditory-Evoked Contralateral Occipital Positivity). However, it is still unclear whether task-irrelevant salient sound processing is solely stimulus-driven or, rather, can be modulated by top-down mechanisms. In the present study, we measured changes in the ERPs and oculomotor activity elicited by task-irrelevant sounds delivered unilaterally during the retention interval of a visual change detection task. Sounds were not included in the current attentional set, so their processing was purely stimulus-driven. Participants had to remember one or four colored squares occurring on the left or right side of the display, while avoiding overt gaze shifts. This manipulation allowed us to explore whether acoustic distractor processing as reflected in the ACOP is affected by endogenous spatial attention and Visual Working Memory (VWM) load. A significant ACOP was observed over parieto-occipital sites in the 280-500 msec time window after sound onset, and its amplitude was modulated by endogenous spatial attention. Specifically, the ACOP was attenuated when the task-irrelevant sound location was opposite to the one of the memoranda, but it was never suppressed. In addition, gaze was directed towards the VWM contents location after the memory array offset, and was never attracted by the acoustic distractor. Therefore, our results suggest that, when eye-movements are discouraged, the oculomotor system is mostly guided by VWM contents instead of being captured by auditory distractors in a stimulus-driven way. The present findings suggest that top-down mechanisms can modulate the extent to which acoustic distractors receive processing resources; however VWM load does not seem to affect the processing of task-irrelevant sounds.

Poster Session I > Attention: Capture 2 > Poster I2

Immunity from Capture: Not!

View Poster | Visit me in Gather.Town Osprey Room on Wednesday 8:00 am - 10:00 am EDT

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The extent to which capture by uninformative peripheral cues is contingent on the top-down goals of the participant has been a hotly debated issue. Most studies have investigated if uninformative cues whose features are irrelevant to the current task goals capture attention. Here (as did Ishigami and colleagues in earlier work), we ask a slightly different, but related question: Do uninformative cues whose locations are irrelevant capture attention? Ruthruff and Gaspelin (2018) presented an abrupt-onset cue among four placeholders (above, below, left & right of fixation). Each participant was asked to find a colour target letter (red or green) among four letters (E/H) in either the horizontal or the vertical axis (by instruction, only one axis was task-relevant) and report its identity; thus cues could be spatially relevant (on the relevant axis) or irrelevant (on the irrelevant axis). Response Times (RTs) on irrelevant-cue trials and absent-cue trials were equivalent suggesting “immunity from attention capture at ignored locations”. We hypothesized that the RTs on absent-cue trials may have been overestimated due to the absence of alerting benefit compared to the cue present trials, and tested this hypothesis in a registered replication study. Experiment 1 replicated the task of Ruthruff and Gaspelin (2018). RTs on irrelevant-cue trials were faster compared to the absent-cue trials lending support to the original conclusion by Ruthruff and Gaspelin that performance does not suffer on irrelevant-cue trials. In Experiment 2, we additionally included a warning signal on every trial to equate all cue conditions on the alerting component. Here, RTs on irrelevant-cue trials were significantly slower than on absent-cue trials suggesting that the irrelevant-cues captured attention, at least to some degree. The results underscore the importance of using an appropriate baseline in attention capture studies.

Acknowledgements: RMK acknowledges support from the Natural Sciences and Engineering Research Council of Canada

Poster Session I > Attention: Capture 2 > Poster I3

Does color priming alter attentional priorities in visual search?

View Poster | Visit me in Gather.Town Osprey Room on Wednesday 8:00 am - 10:00 am EDT

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A salient distractor's ability to capture attention is thought to depend on goals: in search for a known target shape, the presence of a salient-color distractor slows performance when the target is reliably the unique shape (and participants use singleton-detection mode) but not when it appears among heterogeneous shapes (and participants use feature-search mode). However, such control breaks down when the target and distractor colors randomly repeat or swap from trial to trial. In addition, distractor interference is sharply reduced when the colors repeat vs. swap. This color-priming effect is taken to show that selection history guides attention and can override goal-directed control: a color's priority increases if it characterized the target on the previous trial, and decreases if it characterized the distractor. Here, we test an alternative account, according to which color priming reflects how difficult it is to disengage attention from a distractor sharing the previous target's color rather than increased priority of that color. To dissociate priority from disengagement effects, target and distractor colors were selected from four possible colors. Thus, the target color could repeat, be new or swap, i.e., take on the previous distractor's color. Likewise, the distractor could repeat, be new or swap, i.e., take on the previous target's color. Target-color activation (reflected by target repeat vs. new and distractor new vs. swap) modulated distractor interference, supporting the priority account over the disengagement account. However, distractor-color repetition (reflected by distractor repeat vs. new) did not modulate distractor interference, suggesting that it does not underlie resistance to capture by constant distractors.

Poster Session I > Attention: Capture 2 > Poster I4

Information-optimal local features automatically attract covert and overt orienting of attention

View Poster | Visit me in Gather.Town Osprey Room on Wednesday 8:00 am - 10:00 am EDT

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Visual analysis is optimized through the selective sampling of the most salient regions in the scene. Several factors may contribute to the definition of local salience. Here we chose a specific set of local features, predicted by a constrained maximum-entropy model to be optimal information-carriers, as candidate "salient features". Psychophysical and eye movements studies, in which participants were instructed to choose the most salient stimulus, have shown that, in fast vision, these features are perceived as more salient than others, even when shown in isolation. Here, we aimed to show that these features "automatically" attract attention and eye movements in implicit tasks. In a spatial orienting covert-attention task, we presented a tilted gabor on the left or on the right of the fixation point (5º) with different contrasts, preceded by two brief peripheral cues (26 ms), one more salient than the other according to the model. The salient cue is presented on the same side of the gabor in valid trials, with 50% or 80% cue validity. Subjects had to identify the orientation of the gabor as a function of gabor contrast while keeping fixation. In the overt attention task, participants had to perform a saccade towards a circular place holder (target), that could be presented at the salient cue location with 50% or 80% cue validity. Results are coherent in both tasks, showing lower contrast thresholds and saccade latencies in valid trials and higher thresholds and saccade latencies in invalid trials, independently of cue validity, compared to baseline values obtained with equally salient cues. Similar effects were found in a control condition where cues saliency was manipulated through their relative luminance. These findings suggest that in fast vision covert and overt attention are automatically attracted by the saliency provided by the optimal information-carriers features predicted by the reference model.

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Poster Session I > Attention: Capture 2 > Poster I5

Independent time courses for feature-binding errors after attentional capture and disengagement

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Wednesday 8:00 am - 10:00 am EDT

Lasyapriya Pidaparthi[1], Jiageng Chen[1], Andrew B Leber[1], Julie D Golomb[1]; [1]The Ohio State University

As attention dynamically shifts from location to location, feature perception can be altered depending on where spatial attention is allocated. When spatial attention is captured by distracting stimuli, both swapping errors (misreporting a distractor color instead of the target color) and repulsion (perceptual distortion away from a distractor color) can occur (Chen, Leber & Golomb, 2019). We hypothesized that the nature and level of these feature-binding errors may vary from trial-to-trial depending on the degree of attentional capture and efficiency of disengagement; e.g., such that swapping errors occur during capture while repulsion occurs during disengagement from the distractor. To test this, in the current study, we sequentially presented the distractor and target cues with variable delays, with the target stimulus appearing either 50ms or 150ms after the spatial distractor cue, to manipulate the time course of attentional capture and disengagement. Participants reported the color of the target item with a continuous color report, and we used the same probabilistic modeling approach as Chen et al. (2019) to characterize the different types of errors made and their relative proportions. We predicted that the salient distractor would interfere with performance more at the 50ms condition, whereas in the 150ms condition participants would be more likely to have disengaged from the distractor. In line with our predictions, we saw significantly more swapping errors in the 50ms condition than in the 150ms condition. The same pattern, however, was not found with repulsion errors. These differences do not appear to be driven by task difficulty, as the random guessing rate and precision were similar between the two conditions. These results suggest that swapping and repulsion feature-binding errors are observed following different time courses when attention is captured by and disengages from a distractor.

Acknowledgements: NIH R01-EY025648 (JG), NSF 1848939 (JG; AL)

Poster Session I > Attention: Capture 2 > Poster I6

Attentional templates are sharpened through differential signal enhancement, not differential allocation of attention

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Wednesday 8:00 am - 10:00 am EDT

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In visual search, the internal representation of the target feature is referred to as attentional template. The attentional template can be broad or precise depending on the task requirements. In singleton search, the attentional template is broad because the target is the only colored element in the display. In feature search, a precise attentional template is required because the target is in a specific color in an array of varied colors. To measure the precision of the attentional template, we used a cue-target paradigm where cueing benefits decrease when the cue color differs from the target color. Consistent with broad and precise attentional templates, the decrease of cueing effects was stronger in feature than in singleton search. Measurements of event-related potentials showed that the N2pc elicited by the cue decreased with increasing color difference, suggesting that attention was more strongly captured by cues that were similar to the target. However, the cue-elicited N2pc did not differ between feature and singleton search, making it unlikely to reflect the mechanism underlying attentional template precision. Further, there was no evidence for attentional suppression as there was no cue-elicited PD, even in conditions where the cueing benefit turned into a same location cost. However, an index of signal enhancement, the CP, reflected attention template precision. In general, there was sensory enhancement of the stimulus appearing at the cued location in the search display. With broad attentional templates, any stimulus at the cued location was enhanced, whereas enhancement was restricted to target-matching colors with precise attentional templates.

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Visual Search: Attention, models, individual differences

Poster Session I > Visual Search: Attention, models, individual differences > Poster I7

The selection balance: how target value, proximity and priming shape search strategy and eye movement dynamics during visual foraging

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Wednesday 8:00 am - 10:00 am EDT

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Introduction: A critical question in multitarget visual foraging concerns the factors driving the next target selection. Recent theories propose that target selection is achieved in two steps: identification of a set of candidates (through eye movements), and selection of the best option among these candidates (based on internal biases toward proximity, priming or value). However, the role of eye movements in visual foraging is poorly understood. We tested whether eye movements are required for identifying a set of candidates, and whether disabling eye movements during foraging could affect target selection. Methods: We asked 24 participants to perform four foraging tasks differing by selection modality and target value. During gaze-foraging, participants had to accurately fixate the targets to select them and could not anticipate the next target with their eye-gaze. During mouse-foraging, participants selected the targets with mouse clicks and were free to move their eyes. We moreover manipulated target proximity and value, where some targets yielded more points than others. The task was to obtain a prespecified number of points as quickly as possible. Results: The results confirmed that target value and proximity affect all aspects of foraging behavior, from manual reaction times to oculomotor dynamics. Importantly, although the effect of target value was strong for all observers, individual differences were notable, confirming the existence of internal biases towards priming, proximity and value. Moreover, although the results show important differences in oculomotor dynamics between mouse- and gaze-foraging, there were no differences in search strategy (e.g., order of target selections) between selection modalities. Conclusions: Our findings importantly suggest that overt orienting is not necessary for identifying a set of candidates, but that it may be involved in the selection of the best option among these candidates. Our results could therefore provide fundamental information for theoretical conceptions of attentional selection.

Acknowledgements: This work was supported by the Icelandic Research Fund (grant number 206744-051).

Poster Session I > Visual Search: Attention, models, individual differences > Poster I8

Eye Movements in Tablet-based Visual Foraging

View Poster | Visit me in Gather.Town Osprey Room on Wednesday 8:00 am - 10:00 am EDT

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In the visual foraging task, participants search for and collect target elements while ignoring others. This enables the assessment of attention guidance and visual search in a continuous task which is less constrained than traditional visual search tasks. When foraging is performed on a tablet-PC, participants can respond by pointing (or tapping) on targets, and collect items at a high rate. However, this setup makes it challenging to record eye movements, a key indicator of attention. Up to now, tablet-based visual foraging experiments have solely relied on analyzing the manual selection responses. Here we show a novel method and first data from tablet-based visual foraging with eye tracking, enabling an insight into the interplay between manual selections and eye movements. The results highlight a close relationship between eye movements and manual selections. The coupling seems particularly tight in "simple" displays, in which targets are defined via a single feature. Here, selections seem to follow each fixation in a one-to-one relationship. In displays with "conjunction" targets, and particularly within same-type selection runs, gaze and hand movements deviate more from each other. This might reflect increased effort in coordinating hand and eye movements, well in agreement with the finding that foraging efficiency is typically impaired in conjunction conditions.

Poster Session I > Visual Search: Attention, models, individual differences > Poster I9

A two-stage diffusion model in foraging: Simulation and empirical results

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Wednesday 8:00 am - 10:00 am EDT

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Foraging is a type of visual search in which observers look for an undetermined number of targets in a noisy environment. It is a ubiquitous task in human and animal daily life that has received a growing researching interest in the last decade, specifically in human behavior. Foraging in the real world is usually based on non-exhaustive search where the observer is free to abandon the search at will (e.g. berry picking, lego-blocks searches, etc.). Diffusion models have been widely used for modeling many cognitive tasks involving one or two-choice decision processes, including visual search. Here we present a two-stage model based on diffusion processes in the foraging domain with humans: A first stage is based on modeling the decision whether the observer determines if a given item is either a target or a distractor. The second stage models the one-choice decision on when to leave a certain patch/display of stimuli to start a new search or just to quit the search. We present simulation results and applications to experimental data on a large sample of almost 300 participants of different ages (from 4 to 25 years old). Observers must look for different targets in feature and conjunction foraging tasks within a controlled video game-like task. The results show an adequate fit to parameter values consistent with previous diffusion models applications, as well as sensitivity to changes in experimental conditions. The present model provides an innovative way to improve our understanding of foraging research in humans under experimental-controlled conditions by the application of diffusion models within a more mathematical modeling approach.

Poster Session I > Visual Search: Attention, models, individual differences > Poster I10

Can Hybrid Foraging tasks help us to understand attentional problems in development?

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Wednesday 8:00 am - 10:00 am EDT

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Hybrid Foraging (HF) is a visual search task in which observers collect multiple instances of several different target types (e.g. selecting blue-square and purple-rounded Perler-beads to make a craft). Selective attention is a core executive function and recent studies have suggested that HF could be a useful way to study executive functions during development (Ólafsdóttir et al., 2019 & 2020). The goal of the present work is to see how HF is related to performance on the Continuous Performance Test (CPT), a common test in clinical neuropsychology to assess attention-related problems in children. We tested 51 typically developing children (26 aged 5-6 and 25 aged 11-12) using a video game-like hybrid foraging task involving search for well-known stuffed animals. All children also performed the K-CPT/CPT test (for the younger and the older groups, respectively). In the CPT children must respond to one target while withholding responses to distractors. For each observer, we correlated CPT scores with hybrid foraging results. Linear regressions showed that both response times ($F(1, 49) = 8.42$; $p = .006$; $r = .383$) and correct responses ($F(1, 49) = 6.93$; $p= .011$; $r= .352$) were significantly correlated between the two tasks. We found weaker correlations for the omissions ($F(1, 49) = 2.98$; $p = .091$; $r =.239$), probably due to the very different nature of both tasks. While omissions in the CPT respond to the absence of response to the target, in the HF task they are targets not detected and left behind in the search. In general, observers who performed well on one task were likely to do well on the other. HF also provides measures of working memory or attentional shifting (see again Ólafsdóttir et al., 2019 & 2020) making it a promising and powerful task for assessing attention-related problems in development.

Poster Session I > Visual Search: Attention, models, individual differences > Poster I11

Age differences in foraging organization

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Wednesday 8:00 am - 10:00 am EDT

Inga María Ólafsdóttir[1], Steinunn Gestsdóttir[1], Árni Kristjánsson[1]; [1]University of Iceland

Visual foraging involves the search for multiple targets in each display. There can be more than one target types and they are usually surrounded by distractors. The majority of studies on visual attention are conducted with single target search tasks, which does not adequately capture visual orienting over time. By studying visual attention with a foraging task, it is possible to investigate how target selection is organized throughout a trial. We tested the foraging organization of five age groups, children aged 6, 9, 12, 15, and adults, in foraging tasks where targets were either defined by a single feature (color) or a conjunction of two features (color and shape), using two different target types per task. Four

measures were used to assess organizational abilities: intertarget distance, the number of intersections, best-r, and the deviation from the optimal path (percentage above optimal: PAO). We found that foraging organization increased gradually throughout childhood and adolescence, in both the feature and conjunction tasks. At first glance, feature foraging seemed to be more organized than conjunction foraging, but by calculating the best-r and the deviation from the optimal path separately for each target type in the conjunction foraging trials, we found that conjunction foraging is as organized as feature foraging. That indicates that participants treat each conjunction foraging trial as two separate search paths, one for each type of target.

Poster Session I > Visual Search: Attention, models, individual differences > Poster I12

Effects of target value and prevalence on foraging in aging

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Wednesday 8:00 am - 10:00 am EDT

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How do the value and prevalence of targets and the personality of the observer shape visual foraging behavior in younger and older adults? In our “hybrid foraging” task, younger (18-35 years) and older (65-82 years) observers held four different targets objects in memory. They collected multiple instances of those targets from visual displays containing 60-105 moving objects (20-30% targets). Targets were worth points. Observers were asked to reach a point goal as quickly as possible. In three blocks, the point-value and the prevalence of each target type was independently manipulated. Results: Target-value and prevalence shaped foraging behavior. Replicating prior results, observers favored more rewarding and more common items. While the effect of prevalence was highly consistent across observers, individuals varied in the effects of target value; especially when high value items had low prevalence and low value items were common. This condition mimics some real-world foraging situations, e,g, where you prefer the low prevalence cashews in the trail mix, while the cheap raisins and peanuts are more common. In younger adults, personality measures related to reward-seeking behaviour predicted individual selection preferences. Lower reward-seeking was associated with a preference to pick frequent low-value targets over rare high-value items. Second, contrary to our predictions, we did not find age differences in the responsiveness to target value and prevalence. The effects were strikingly similar across age groups. This finding argues against genuine age-differences in the processing of reward-values. Rather, our results support consistency in the impact of reward on visual processing across the adult lifespan, as long as both younger and older adults can meet the learning requirements of the task.

Acknowledgements: This work was supported by the European Union’s Horizon 2020 research and innovation programme, Marie Sklodowska-Curie Actions, under grant 702483 (IW); and the National Insititutes of Health under grant NIH EY017001 (JMW)

Poster Session I > Visual Search: Attention, models, individual differences > Poster I13

Individual Differences in Inattentional Blindness in Visual Search

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Wednesday 8:00 am - 10:00 am EDT

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Inattentional Blindness (IB) is the failure to notice (or, at least, to report) a salient, but unexpected event. It is a theoretically important phenomenon that may be related to the failure to report “incidental findings”, important items that are not the primary target of search in tasks like medical image analysis or security search. Age, Intelligence Quotient (IQ), and expertise are among the variables proposed to be related in susceptibility to IB. However, the prior results have not been consistent enough to convincingly identify the critical variables. In the present work, we studied a large sample of 277 observers from 4 to 25 years old. All participated in the same visual search task where targets and distractors were real-world objects. On two, separate trials during the task, a letter and a word were presented unexpectedly among the objects. At the end of the task, observers were asked about the letter and the word using both free-recall and recognition questionnaires. All participants were tested on an IQ-proxy test (RIST) and attentional test (Continuous Performance Test - K-CPT or CPT, depending on age). We found significant age differences in IB for both the letter and the word IB stimuli, showing that younger children have more trouble noticing the unexpected stimuli. The age effects on

IB differed for the letter and the word, showing that IB can be stimulus-dependent. For word-IB, CPT inattention-related variables also correlated with IB showing higher IB levels for higher inattention levels. Neither gender nor IQ had significant effects on IB. The results show that age and in(attention) can be important variables affecting how distractors are processed in visual search. We did not find evidence for a relationship between IB and measures of intelligence though we note that, as a negative finding, this result should be treated with caution.

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Poster Session I > Visual Search: Attention, models, individual differences > Poster I14

High Level Feature Search in Autism Spectrum Disorder

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Wednesday 8:00 am - 10:00 am EDT

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Introduction: Visual search is a most-studied cognitive behavior. Anne Treisman introduced classification of easy, “pre-attentive” feature search, (search for elements which differ greatly from distractors in simple features), which leads to rapid target “pop-out,” versus more difficult search with focused attention, (e.g. search for feature conjunction), where target detection depends on set size (number of display items). This search-type dichotomy has been found also in children. Finding that conscious vision is initiated through representations at higher cortical levels, Hochstein & Ahissar (2002) suggested Reverse Hierarchy Theory, whereby initial “vision at a glance” depends on higher cortical representations suggesting, and later found (Hershler & Hochstein, 2005, 2006) that fast, easy feature search is associated with higher cortical levels so that faces, too, pop out. Disorders on the autism spectrum (ASD) are often characterized by difficulties in face recognition, while there is some evidence of speeded visual search in children with ASD. Methods: We presented displays with 4, 16, 36, or 64 pictures of different category objects, including one target picture of a face, car, house, or animal, dog or lion faces and measured response time (RT) to touching the target item on the screen – for neurotypical and ASD children, matched for age and IQ (block-design: WISC-IV; WAIS-III). Average Autism Spectrum Quotient test (AQ) was 27 for the ASD group vs. 11 for the NT group; t-test p<0.0001. Results: Face detection is different for the two groups, with average set-size slope of 16 (ASD) vs. 11 (NT) ms/item, t-test p<0.005. Face detection is only slightly affected by IQ. Detection of other categories is not affected on average by ASD, with an average set-size slope of 78.6 vs. 78.2; p=0.48. Conclusions: Children on the autism spectrum have more difficulty than neuro-typical children in finding a face among pictures of other categories.

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Poster Session I > Visual Search: Attention, models, individual differences > Poster I15

Maximizers and Satisficers in Visual Search: Extra Effort Doesn’t Guarantee Additional Reward

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Bounded rationality prevents human decision-makers from acting optimally all the time; often, its necessary to accept a “good enough” solution when it’s impossible to explore every alternative. Maximizers aim to discover all possibilities and select only the best option, while satisficers select the first acceptable option. Previous research on choosing among alternatives has shown that maximizers outperform satisficers on objective measures of performance, but are worse on subjective measures. The present studies aim to broaden the scope of the existing maximizing literature (for review, see Cheek & Schwartz, 2016) to encompass visual search. Critically, we change the underlying question from how individuals select among an array of options to how they identify whether a single item is present. In two experiments, participants completed numerous personality assessments, including a maximizing tendency scale, and performed a visual search task where they identified whether a target letter was present or absent from the display. The top and bottom quartiles of the maximizing scale were classified as maximizers and satisficers, respectively. In Experiment 1, items appeared in set sizes of 20, 30, or 40, with 50% target presence. Results indicated no difference between maximizers and satisficers in terms of accuracy or response time, however non-significant differences in response time began to emerge at set size 40. Experiment 2 included larger set sizes (40, 60, 80) to accentuate the trending differences between groups found in Experiment 1. Results indicated no group differences in accuracy, and a marginal effect of response time (~2.5-3s difference). Specifically, maximizers responded more slowly than satisficers, but without improving accuracy. Overall, these results suggest that contrary to expectations, satisficers may perform better on a visual search task than maximizers, but only when it is difficult, as they are able to achieve equal levels of accuracy as maximizers, in less time.

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Gaze behaviour when visually searching for targets to be reached toward is influenced by movement-related costs imposed by obstacles

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Real world action tasks often involve operating in a cluttered environment, in which we search for a target object among distractors. In many cases, the structure of these environments dictate large movement costs associated with reaching the located target (e.g., reaching a cup on a high shelf). While it is well established that people are sensitive to movement costs when selecting between potential movements, it is unclear whether movement costs likewise influence visual search behaviour. Here we tested whether visual search behaviour, as measured by gaze, is biased by the movement costs associated with acting on a target object. In each trial, an obstacle was briefly displayed and then a set of 36 objects, including 4 targets and 32 distractors, were displayed. The length, location, and orientation of the obstacle and the locations of the target objects were randomly varied. The task was to locate a target and then reach for it using a cursor controlled by the handle of a robotic manipulandum. The handle could apply forces simulating any contact between the cursor and the unseen obstacle. The cursor start position was in the center of the display and the objects in a given trial were either on the 'near' or 'far' side of the obstacle. We found that search, and hence target selection, was biased towards the near side of the obstacle, thus reducing the time and energy costs associated with reaching. This result suggests that humans can readily incorporate the movement costs of an environment when forming visual search strategies.

Acknowledgements: NSERC Discovery grant to JRF

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How does multidimensional complexity impact processing efficiency in visual search?

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In visual search, the more similar the target to the distractors, the less efficient the search; the less similar the target to the distractors, the more efficient the search. Very little has been done to understand how similarity arises in multi-dimensional stimuli. In previous work, we have studied how bi-dimensional dissimilarity arises when stimuli differ along two feature dimensions in efficient search (color and shape; shape and texture; color and texture). Here, we report our first evaluation of how visual complexity arises when the target differs from distractors along three feature dimensions (color, shape and texture). In Experiments 1-3, we first tested people's search efficiency when the target differed from a set of homogeneous distractors either along color (a red target among green, pink or orange distractors), shape (an octagon target among triangle, square or house-shape distractors), and texture (a cross-textured target among dotted-, hashed- or solid-textured distractors). In Experiments 4-12, we fully crossed all possible combinations of the tested distractor colors, shapes and textures to define the multidimensional distractor stimuli (e.g., green-dotted triangles, pink-hashed squares). We used a model comparison approach to evaluate the extent to which efficiency in Experiments 1-3

could predict performance in Experiments 4-12. We used computational modeling to understand the mechanistic instantiation behind the competing models. Our results suggest that three-dimensional search efficiency (R-squared = 0.85 over 27 datapoints) as well as RT (R-squared = 0.86 over 108 datapoints) were best predicted by a model where all three dimensions are racing towards a rejection threshold simultaneously. The race occurs at each item location independently and results in substantial processing efficiency savings. From an information processing standpoint, this is the most efficient manner to discard unlikely targets. These findings suggest that search efficiency might be driven by different forces in uni-dimensional compared to multi-dimensional contexts.

Acknowledgements: This material is based upon work supported by the National Science Foundation under Grant No BCS1921735 to SB.

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Exploring the gist-based modulation of learning rate in visual search

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Scene categorization is a rapid and automatic visual perceptual process, occurring with less than 100 milliseconds of exposure to a natural scene image. Why do humans have this exceptional ability to immediately, and efficiently, grasp gist information? One prominent theory (Torralba et al., 2006) suggests scene gist is rapidly perceived in order to guide exploration of our visual environment towards information-rich regions (e.g., countertops in a kitchen). Such gist-based guidance allows for efficient sampling of behaviourally relevant information contained within the visual scene. This semantic information has been shown to guide attention and visual search alongside bottom-up and top-down influences. Currently, there is little agreement about whether scene gist can be used to guide attention. Across three experiments, we test the hypothesis that rapidly available guidance signals from scene gist can be leveraged to learn new attentional strategies. All experiments were variations on the scene-preview paradigm (Castelhano & Heaven, 2010). After being presented with a preview containing a degree of information relevant to the search image, participants were instructed to find a target embedded in a naturalistic scene. Critically, target location was linked to scene gist, such that the target appeared in a consistent location determined by the scene's conceptual category. The three experimental variants are as follows: 1) within-subject and pictorial search previews, 2) within-subject and semantic search previews, and 3) between-subjects and pictorial search previews. Across these experiments, we find evidence that activating gist with scene previews increases search efficiency. Preliminary computational analyses with a combined model of visual perception (VGG16) and category learning suggest this search benefit arises in a manner consistent with formal theories of skill acquisition. These findings are consistent with a flexible learning system that leverages scene gist information in novel ways to improve visual search efficiency.

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Object Recognition: Models

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Deep Neural Network Selectivity for Global Shape

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Wednesday 8:00 am - 10:00 am EDT

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Background: Deep convolutional neural networks (DCNNs) trained to classify objects have reached remarkable levels of performance and are predictive of brain response in both human and non-human primates. However, DCNNs rely more on texture than shape relative to humans (Baker, Lu, Erlikhman & Kellman, 2018; Geirhos et al., 2018), and also appear to be biased toward local shape features (Baker et al., 2020, but see Keshvari et al. 2019). Here we employ a novel method to test for DCNN selectivity for the global shape of an object. Method: We used a dataset of animal silhouettes from 10 animal categories. To assess selectivity for global shape, we created two variants of these stimuli that disrupt the global configuration of the object while largely preserving local features. In the first variant, we flipped the top portion of the object left-to-right but maintained its smooth connection with the bottom of the object, thus disrupting global shape but preserving object coherence. In the second variant we also shifted the top portion laterally so that both global shape and global coherence were disrupted. We then analyzed the classification performance of the Resnet50 DCNN (He et al., 2016) on these stimuli, using two different training curricula: ImageNet alone, and ImageNet + Stylized Imagenet, which has been reported to improve performance on silhouettes (Geirhos et al., 2018). Results: We found that disrupting global shape while maintaining local shape and object coherence induced a ~60% drop in classification performance, while also disrupting coherence induced an additional ~80% drop. Interestingly, co-training on Stylized Imagenet did not mitigate these impacts and reduced performance on silhouettes overall. Implications: While prior work suggests that DCNNs are biased toward texture and local shape features, our findings suggest that at least some ImageNet-trained DCNNs are profoundly selective for global shape and object coherence.

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Increasing neural network robustness improves match to V1 eigenspectrum and improves V1 predictivity

View Poster | Visit me in Gather.Town Osprey Room on Wednesday 8:00 am - 10:00 am EDT

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Convolutional neural networks (CNNs) show striking similarities to the ventral visual stream. However, their image classification behaviour on adversarially perturbed images diverges from that of humans. In particular, human-imperceptible image perturbations can cause a CNN to misclassify the image. Recent work suggests that the degree to which a system is robust to these perturbations could be related to the power law exponent, α, of the eigenspectrum of its set of neural responses. Informally, the theory states that if $\alpha < 1$, then small perturbations to a stimulus could result in unbounded changes to the neural responses. Here, we test this hypothesis by comparing predictions from a set of standard and “robust” CNNs with neural responses in rodent and macaque primary visual cortex (V1). Specifically, we relate these models’ V1 fit quality with their accuracy on adversarial images, and their power law exponents. For both macaque and rodent neural responses, we found that model correspondence to V1 was correlated with adversarial accuracy. We then investigated the relationship between α and adversarial accuracy. When comparing a non-robust model with its robust counterpart, we found that all robust counterparts had higher α. Between α and V1 response predictivity, we similarly found that the robust counterparts of non-robust models had higher α and higher V1 predictivity. Across architectures, however, there was no relationship between these two quantities. Finally, we found that neurons in robust models were generally tuned to lower spatial frequencies than those of non-robust models and that adversarial accuracy was somewhat negatively correlated with spatial frequency tuning. These observations suggest that developing biologically plausible techniques to increase α (e.g., by reducing representation dimensionality) for a given architecture and to bias models to learn image features of lower spatial frequencies may improve tolerance to perturbations and V1 response predictivity.

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Is initial training with blurry images beneficial for the development of object recognition systems?

View Poster | Visit me in Gather.Town Osprey Room on Wednesday 8:00 am - 10:00 am EDT

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A recent study claimed that the initially poor visual acuity of infants might be critical for the visual system to learn to integrate information over larger spatial scales. Specifically, when convolutional neural networks (CNNs) were initially trained on blurry face images, followed by progressively clearer images, the CNN acquired robustness to variations in spatial resolution (Vogelsang et al., 2018). Here, we asked whether initial training with blurry images would confer a similar benefit to general object recognition, possibly offering a clue to the robust nature of human vision. To evaluate this question, we trained AlexNet with 1,000 ImageNet object categories in which the resolution of inputs was gradually increased over training epochs. Although training with blurry objects initially led to good performance on blurry test images, such robustness to blur soon disappeared after training with clear images. These findings deviated from the robustness to blur that occurred for a CNN trained with face images. Curiously however, we found that a CNN trained

concurrently on faces and objects, progressing from blurry to clear, lost the ability to recognize both blurry faces or objects. This problem of catastrophic forgetting can be attributed to the fact that proportionally greater discriminating information resides in the higher spatial frequencies of objects as compared to faces. As the CNN learns to leverage this finer scale information, it tends to lose the ability to leverage information at coarser spatial scales for both objects and faces. While our findings do not rule out the possibility that poor initial acuity might lead to important developmental benefits in face recognition ability, they do bring into question whether people's ability to recognize blurry faces and objects in adulthood can be explained by these early experiences alone.

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Representing contextual associations in convolutional neural networks

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Contextual associations play a significant role in facilitating object recognition in human vision. However, the role of contextual information in artificial vision remains elusive. We aim to examine whether contextual associations are represented in an artificial neural network, and if so, to understand at what layer they potentially have a role. Addressing this, we examined whether objects that share contextual associations (e.g., bicycle-helmet) are represented more similarly in convolutional neural networks than objects that do not share the same context (e.g., bicycle-fork), and further examined where in the network these context-based representational similarities emerge. As a comparison, we also examined the representational similarity of objects that belong to the same category (e.g., two different shoes) in contrast to objects that do not share the same category (e.g., shoe-brush). In a VGG16 neural network trained on ImageNet and focused on object categorization, representational similarity among objects that share a context (N = 70) is substantially higher than similarity among objects that do not share a context. Representational similarities were computed as the correlation between unit responses to pairs of images in and out of context (or category as a comparison). This context-based rise in similarity emerged at very early layers of the network, remarkably, at the same layer that category-based similarity was found. Category-based similarity was significantly larger than context-based similarity throughout the network. Pixel similarities across contextually paired objects were no greater than objects that do not share the same context. Thus, even though the network was designed for categorical object recognition, contextual relationships were evident in the network across early, mid, and late layers. This suggests that context is inherently preserved and represented across the network, and may have a critical role in facilitating object recognition both in humans and in artificial models.

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Quantifying Adversarial Sensitivity of a Model as a Function of the Image Distribution

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In this abstract, we propose an adaptation to the area under the curve (AUC) metric to measure the adversarial robustness of a model performing an object classification task over a particular epsilon-interval (interval of adversarial perturbation strengths) that facilitates comparisons across models when they have different initial performance under the Fast Gradient Sign Method (FGSM) attack [Goodfellow et al. 2014]. This can be used to determine how adversarially sensitive a model is to different image distributions (or some other variable); and/or to measure how robust a model is comparatively to other models. We used this adversarial robustness metric on MNIST, CIFAR-10, and a Fusion dataset (CIFAR-10 + MNIST) where trained models performed either a digit or object recognition task using a LeNet, ResNet50, or a fully connected network (FullyConnectedNet) architecture and found the following: 1) CIFAR-10 models are more adversarially sensitive than MNIST models when attacked using FGSM; 2) Pretraining with a different image distribution and task sometimes carries over the adversarial sensitivity induced by that image distribution and task in the resultant

model; 3) Both the image distribution and task that a model is trained on can affect the adversarial sensitivity of the resultant model. Collectively, our results imply non-trivial differences of the learned representational space of one perceptual system over another given its exposure to different image statistics or tasks (mainly objects vs digits). Moreover, these results hold even when model systems are equalized to have the same level of performance, or when exposed to approximately matched image statistics of fusion images but with different tasks. Altogether, our empirical analysis of the adversarial sensitivity of machine vision systems provides insights into understanding the interplay between the learned task, the computations in a network/system, and image structure for the general goal of object recognition.

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A Signature of Orientation Invariance in Human fMRI & (Some) Deep Neural Networks

View Poster | Play Video | Visit me in Gather.Town Osprey Room on Wednesday 8:00 am - 10:00 am EDT

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Deep neural network (DNN) models capture the representational geometry of neural responses to different objects (Yamins & Dicarlo, 2016), but do they show the same hallmark invariances as human vision? In the human visual system, orientation invariant representations (consistent responses to an item viewed at different angles) emerge abruptly between V3 and LOC (Morgan & Alvarez, 2014). Here, we ask where (if anywhere) orientation invariance emerges in DNNs, and whether that invariance mirrors the invariance we observe in humans. Using a large battery of DNNs (both trained and randomly initialized, from model zoos including Torchvision and the Taskonomy project), we extract the responses of each layer of each network to a series of 8 stimuli at 5 different degrees of rotation (0-45-90-135-180) – the same stimulus set used in the human fMRI. We then assess the representational similarity of each stimulus to the same stimulus at different rotations ("within-category" similarity) and to different stimuli at the same rotation ("across-category" similarity) in each layer of the network and each area of the brain. We compare the DNN responses directly to the fMRI responses with a second Pearson distance metric across the aggregated similarities (within- and across-category). In the end, this process produces a similarity score for each DNN layer to each area of the brain. Smoothing across the layer-wise similarity scores in each network with a generalized additive model (GAM), we show that in the majority of trained models we test, earlier and intermediate layers of the network are more similar to brain areas with little to no invariance (EVC / OPC) and later layers (usually following a fully connected layer) are more similar to brain areas with strong invariance (LOC / OTC). Overall, our results provide a preliminary signature of human brain-like orientation invariance in deep neural networks.

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High-performing computational models of visual cortex are marked by high intrinsic dimensionality

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A central goal of cognitive neuroscience is to understand the computational properties of neural representations in visual cortex. Above and beyond the information content or visual features encoded in neural populations, we wish to understand the encoding format itself and the computations it subserves. These questions are at the heart of research into computational properties such as sparsity, dimensionality, manifold geometry, invariance, and dynamics in both biological and artificial neural networks. Here we investigate the computational properties of representations across human visual cortex using fMRI encoding models. We first fit voxelwise encoding models to predict fMRI responses to images of natural objects and scenes using both hand-engineered feature detectors (e.g. edge detectors) and pre-trained and untrained convolutional neural networks (CNNs). We then performed statistical analyses of the encoding model regressors to explore how performance is affected by several computational properties, including mixed selectivity and intrinsic dimensionality. We searched for the properties that correlated best with encoding accuracy. We find evidence for high intrinsic dimensionality as an important driver of encoding model performance across the ventral and dorsal visual streams. Furthermore, we find that several mechanisms for increasing intrinsic dimensionality lead to

similar improvements in encoding model performance, including division normalization, multiplicative interaction, random nonlinear projection, and supervised learning for image classification. Thus, it appears that intrinsic dimensionality itself best explains the improvements of these varied representational mechanisms. Together, our work explores a methodology for investigating the computational properties of neural representations through an ensemble of encoding models and statistical analyses of their computational properties. We use this approach to identify high intrinsic dimensionality as a key predictor of encoding model performance, suggesting that biological vision relies on representations that are highly efficient, and may allow for the linear separability of a large number of visual properties across different tasks.

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Hierarchically Local Tasks and Deep Convolutional Networks

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The main success stories of deep learning in visual perception tasks starting with ImageNet, has relied on convolutional neural networks, which on certain tasks perform significantly better than traditional shallow classifiers, such as support vector machines. Is there something special about deep convolutional networks that other learning machines do not possess? Recent results in approximation theory have shown that there is an exponential advantage of deep convolutional networks (DCN) over fully connected networks (FCN) in approximating functions with hierarchical locality in their compositional structure. These mathematical results, however, do not say which tasks are expected to have input-output functions with hierarchical locality. Here we explore a set of hierarchical and non-hierarchical visual tasks in which we study how network performance is affected by disrupting locality through scrambling in the input image space. In particular our experiments consist of having 2 distinct networks that vary in their computation: a fully connected network that has no locality prior, and a deep convolutional network that has a locality prior. These networks performed 3 tasks: Color Estimation (that does not require locality), Object Classification and Scene Gist. We verify that fully connected networks that possess no locality prior stay stable (albeit weaker) in performance even as the images are scrambled, across all the 3 tasks --with the exception of the color estimation task where although performance does not change, and FCNs achieve superior performance to that of DCNs. However, when the images are fully scrambled, we find that deep convolutional networks can perform worse than fully connected networks across all 3 tasks --with little variation for a non-hierarchical task. Finally, we show that small departures from the locality bias grow during learning with gradient descent even on a hierarchical task, suggesting that this bias cannot be purely learned from data without additional constraints.

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VISCNN: A tool for Visualizing Interpretable Subgraphs in CNNs

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Deep, convolutional neural networks (CNNs) have become prominent models of biological visual processing, but have been criticised as replacing one black-box (the brain) with another (the CNN). To help address this critique, we present a new tool for visualizing interpretable subgraphs in CNNs (VISCNN) that can both enhance interpretability of CNN computations and help guide hypothesis generation. Olah et. al. 2020 showed that CNNs can be decomposed into small, interpretable circuits, which combine simple feature detectors into complex ones. What remains unclear from their work is how one finds such circuits in a quantitatively principled way, given the combinatorially explosive number of possible subcircuits from pixel-space to a downstream feature in a deep CNN. VISCNN is a software tool that enables this, by allowing researchers to query CNNs for circuits that generate features of interest. The tool identifies parts of a CNN's computational graph that would significantly affect some target feature's expression were they to be removed, and weights the preceding nodes and edges in the graph accordingly. The researcher can then quickly and intuitively explore the latent data-processing streams in their CNN models, by first querying for subgraphs, then clicking through the returned nodes and edges to view underlying feature visualizations (Olah et. al. 2017), activation maps, and

convolutional kernels. VISCNN works by repurposing metrics used in neural network pruning, which conventionally rank neural network units based on their importance for preserving the final loss. Following Molchanov et. al. 2017, we can approximate the importance of any intermediary activation map for a downstream feature. VISCNN transforms modern computer vision models into easily-explorable empirical objects for the vision science community to study. There are doubtless many interesting latent computations performed by such models, and VISCNN allows researchers to probe this vast space of computations for targeted, interpretable circuits.

Synthesizing preferred stimuli for individual voxels in the human visual system

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Investigating the function of the various subregions of the visual system is a major goal in neuroscience. One approach is specifying to which types of stimuli they show the strongest response to, however given the variety of the visual world it is impossible to present all possible stimuli in-vivo. We follow an alternative approach to reach this goal. We trained a convolutional neural network-based model of the occipitotemporal cortex to match the behaviour of an individual brain reacting to visual input, using a large-scale functional MRI dataset (Seeliger & Sommers 2019). This model allowed us to predict voxel responses in several areas defined functionally (such as FFA, LOC, PPA) and from an anatomical atlas (such as PHC, VO) in-silico. To identify the preferred stimuli for voxels in these areas we developed an interpretability technique for convolutional neural networks, based on a generative adversarial neural network (GAN), and using gradient ascent for synthesizing naturalistic preferred images. As expected, voxels in areas V1-V3 yielded small receptive fields with a preference for gratings. Higher order areas showed mixed preference: For instance, while confirming face-selectivity in FFA and place-selectivity in PPA, both regions additionally showed preference for other visual features, such as oval shapes and vertical lines in FFA, or horizontal lines and high spatial frequency in PPA. The GAN latent vectors for the investigated subregions were highly distinct, as shown in classification tasks, underscoring the validity of the results. This approach opens the avenue towards precision functional mapping of selectivity at the level of individual voxels across the whole visual system, and may reveal previously unknown functional selectivity.

Acknowledgements: This work was supported by a Max Planck Research Group grant to M.N.H.

A unifying parametric language and a toolbox for future investigations of the role of the medial axis parameters in human vision.

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From a very young age, humans are able to recognize objects or living beings while they move and assume different postures. This ability to recognize object identities through flexible aspects could be based on invariant properties of shapes, such as for example the properties put forward by the formalism of the medial axis theory (also called skeleton theory). This formalism, which was originally designed to describe organic shapes such as bodies or plants, can indeed easily capture “natural” invariances, such as the shape of an animal’s body as it moves. Several behavioral or brain imaging studies have started to highlight the role of the medial axis parameters in human vision, including in categorization. However, all these studies used different characterizations of the medial axis properties, making it hard to compare their results. In particular, across studies the authors manipulated different aspects of the shapes and their medial axes and used different measures to quantify skeletal similarities. Our work had two aims. First, we created a formal mathematical space providing a full description of shapes in the language of the medial axis formalism, which can be used as a unifying framework for cognitive research. For this purpose, we defined three families of parameters: topological parameters describing the structure of the skeleton in the format of a non-measured graph; skeleton parameters specifying the details of the shape’s skeleton; and growth parameters describing how the shape can be grown from its skeleton. Second, we also implemented a Matlab toolbox generating shapes specified in the vocabulary of these medial-axis parameters, and selectively manipulating each skeleton and growth parameter in isolation. In

conclusion, our work introduces both a unifying parametric language and a methodological tool paving the way for future systematic investigations of the role of the medial-axis parameters in human vision.

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Bayesian inference of population prevalence

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Within neuroscience, psychology and neuroimaging, the most frequently used statistical approach is null-hypothesis significance testing (NHST) of the population mean. However, an alternative and equally valid question to ask about a population is how typical is the effect? To address this question, we infer an effect in each individual of the sample, and from that infer the prevalence of the effect in the population—i.e. the proportion of the population that would show the effect, if tested. We propose a novel Bayesian method to estimate such population prevalence that offers several advantages over population mean NHST. This method provides a population-level inference that is currently missing from study designs with small participant numbers, such as in traditional psychophysics and in precision neuroimaging. It delivers a quantitative Bayesian estimate of the prevalence of the effect in the population, with associated uncertainty, instead of reducing an experiment to a binary inference on a population mean. With simulations and examples from behavioral experiments, EEG and fMRI we show that the results obtained using population mean versus population prevalence can differ, particularly when effects are heterogenous across participants. We show how difference in prevalence can be directly estimated between and within groups, and how prevalence of different effect sizes can reveal a more detailed picture of the population. We argue that in many experimental applications in psychology and neuroscience, the individual participant is the natural replication unit of interest. However, within-participant results are usually viewed as fixed-effect case studies without a formal inference to the population. Bayesian prevalence provides this link. Bayesian prevalence is widely applicable to a broad range of studies in neuroscience, psychology and neuroimaging. Its emphasis on detecting effects within individual participants could also help address replicability issues in these fields.

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Object Recognition: Categories 2

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A deep neural network trained with human-like visual experience on lookalike objects, perceives animacy in lookalike objects similar to the brain.

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Humans can categorize everyday objects with visual animal features (e.g. a cow mug) as objects, which is also true for deep neural networks. This is not the case in the brain, where ventral occipitotemporal cortex (VTC) representations do not represent these objects as objects, but rather as animals (Bracci et al., 2019). Here, we investigate to what extent such effects might be due to training history. More specifically, we determined whether further training the pre-trained network model AlexNet (i.e. transfer learning) can lead to higher resemblance to VTC performance. We applied three different transfer training regimes: animal <> lookalike <> object (3 categories), animal + lookalike <> object (2 categories), and animal <> object + lookalike (2 categories). After training, image features are extracted from the second to last fully connected layer (FC7). The results show that when training the network with a clustered dataset (e.g. animal + lookalike) the representational similarity in FC7 for the individual clustered categories (e.g. animals and lookalikes) increases relative to the third category. Furthermore, after training with the animal + lookalike clustering, FC7 representations are more correlated with VTC representations than after any other training regime. These findings support the hypothesis that the bias in human cortex to represent lookalikes as animals could be due to the training history during human development. Bracci, S., Ritchie, J. B., Kalfas, I., & Op de Beeck, H. P. (2019). The Ventral Visual

Pathway Represents Animal Appearance over Animacy, Unlike Human Behavior and Deep Neural Networks. The Journal of Neuroscience : The Official Journal of the Society for Neuroscience, 39(33), 6513–6525. https://doi.org/10.1523/JNEUROSCI.1714-18.2019

Poster Session I > Object Recognition: Categories 2 > Poster I33

The Role of Retinal Position and Semantic Relatedness of Objects on The Familiar-Size Stroop Effect

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Visual perception is driven by expectations regarding familiar concepts and relations in the real world. For instance, trees are expected to be big and apples to be small. Such expectations help to guide behavior and cognition by generating predictions that boost the efficiency of visual processing. When judging which of two objects is visually smaller on the screen, reaction time (RT) is longer if the visual size of the items is incongruent with their real-world size (e.g. a small tree next to a big apple) compared to when it is congruent - despite the fact that real-world size is task-irrelevant (Konkle & Oliva, 2012). Here, we replicated this familiar-size Stroop effect and additionally assessed the influence of retinal position (Experiment 1) and semantic relatedness among objects (Experiment 2). In both experiments, two objects were presented on the same horizontal plane on the left and right of a centered fixation point. In Experiment 1, both objects were either positioned in the center or in the periphery. We found Stroop effects of similar magnitudes for both positions. Further, while there was no difference in the number of errors, RT was overall longer for peripheral positions. This delay in RT could be related to reduced recognizability of the objects under peripheral viewing and/or the fact that there was an increased distance between the objects in the periphery. The rationale for Experiment 2 was based on research that found semantically related objects to be recognized better than unrelated objects (e.g., toaster and refrigerator vs. toaster and shower). However, we found no evidence that a manipulation of semantic relatedness affects the Stroop effect. In sum, our findings indicate that objects' real-world size is automatically processed not only in central but also in peripheral vision, and regardless of whether neighboring objects are semantically related or not.

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Poster Session I > Object Recognition: Categories 2 > Poster I34

Limitations on Animacy Categorization in Ensemble Perception

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People can rapidly and efficiently categorize the animacy of natural objects. Does this imply that the visual system has an unlimited capacity for processing animacy across the entire visual field? To test this, we generated a set of morphed "animacy continua" between animate and inanimate silhouettes. Observers were shown different ratios of these items (2:1, 10:3) and judged whether a set was more animate/inanimate. The distribution of items was either "segmentable" (including only 100% animate/inanimate items) or "non-segmentable" (50% ambiguous morphs were also presented). In Experiments 1 and 2 (N=61), observers failed to integrate animacy from multiple items, as they showed very poor performance and were not sensitive to the distribution type, despite an almost perfect ability to categorize individual objects. The same manipulation with color as a category-defining feature elicited both good individual and ensemble categorization performances and the segmentability effect. In Experiment 3, we parametrically manipulated feature discriminability in both color and animacy to ensure our results were not based on different discriminability. We always presented "segmentable" distributions with a 2:1 numeric ratio and used two levels of color discriminability (easy and hard – 30˚ and 15˚ apart along a CIELab color wheel) and three levels of animacy discriminability (hard – ambiguous morphs of objects, easy – morphed but not ambiguous objects, non-morphed – original silhouettes of real objects). The results again showed that observers were bad at ensemble animacy categorization even at high discriminability and

rather good at the color ensemble task even at low discriminability (although they were almost perfectly accurate at individual categorization for both features). Thus, discriminability alone cannot explain the differences in performance for two dimensions. Overall, we conclude that good individual categorization does not always allow people to build strong ensemble animacy representations, which suggests the limited capacity of animacy perception.

Acknowledgements: Russian Science Foundation (18-18-00334)

Poster Session I > Object Recognition: Categories 2 > Poster I35

On the time course of Conscious and Unconscious Semantic Processing

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Previous research suggests that conscious and unconscious processing follow different time courses. Early studies showed that primes' impact on responses to subsequent targets survives only short prime-target intervals for subliminal primes, but lasts longer for supraliminal primes. However, this dissociation may reflect differences in stimulus strength rather than in conscious perception. Later studies showed that with liminal primes, for which conscious and unconscious processing can be compared under the same stimulus conditions, unconscious priming occurs only for fast responses, whereas conscious priming remains stable across the RT distribution. This dissociation may reflect decay of unconscious representations. However, it could also reflect that fast responses, unlike slow responses, rely on fast-and-dirty processing that is particularly sensitive to unconscious information. Finally, these dissociations were reported for semantic priming and whether they hold for lower-level prime representations is unclear. Here, we used the liminal-prime paradigm and measured repetition priming, response priming from learned stimulus response associations and semantic response priming. We forced participants to rely on fast, intuitive processing by imposing a short response window, and manipulated prime-target intervals. Both response priming effects quickly waned for unconscious primes and generally increased for consciously perceived primes. By contrast, repetition priming was independent of conscious perception and increased with prime-target interval. These findings suggest that conscious perception prevents decay of the prime's impact on response selection. However, the different pattern observed for repetition priming calls for further research on the longevity of unconscious effects that are not mediated by response priming.

Eye Movements: Perception, neural mechanisms

Poster Session I > Eye Movements: Perception, neural mechanisms > Poster I41

Perceived timing of stimuli briefly stabilized on the retina during microsaccades

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When saccades are generated, the retinal motion that would dominate the visual input during the eye movement is not perceived. Instead, post-saccadic percepts shift backwards in time—pre-dating the new fixation to before saccade onset (Hunt & Cavanagh, 2009). We investigated whether saccades must be voluntarily initiated and consciously controlled for this temporal expansion to take effect, and probed the visual system's ability to estimate the timing of stimuli during microsaccades—a very fast type of spontaneous, unconscious miniature eye movement taking place during intended fixation. We displayed a vertically oriented, high-contrast Gabor (4 cpd) and shifted its phase at high temporal frequencies (>60 Hz). This internal stimulus motion rendered the Gabor invisible against a gray background during stable fixation. However, microsaccades that matched the phase shift's direction and speed briefly stabilized the Gabor on the retina and could therefore lead to its detection. Observers reported the time point of stimulus detection by adjusting a clock hand at the end of the trial, allowing us to determine when a stimulus was perceived. Observers reliably detected the Gabor during microsaccades: Visual sensitivity depended on the match of the microsaccade's to the phase shift's velocity and direction, increasing with larger similarities between these metrics. Replaying the retinal consequences of an observer's previous microsaccades bore out remarkable similarities to these findings, suggesting that visual sensitivity during microsaccades is not limited per se. Interestingly, temporal adjustments revealed that 7 out of our 10 observers reported stimuli earlier when seen during self-generated compared to replayed microsaccades. Our data thus indicate that correlates of active microsaccade generation are used for the temporal processing of stimuli even in the absence of conscious, volitional control of the eye movement: The generation of microsaccades informs the timing of visual events, pre-dating it relative to the arrival of sensory input.

Poster Session I > Eye Movements: Perception, neural mechanisms > Poster I42

The Effects of Abutting Pattern Motion and Smooth Pursuit Eye Movement on the Visibility of Low-Contrast Luminance-Modulated Target Gratings

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Contrast sensitivity to low-contrast luminance-modulated target gratings is higher when presented at the leading edge of an in-phase abutting inducer, rather than at the trailing edge (N.W. Roach, P.V. McGraw, A. Johnston, 2011). This phase-contingent facilitation effect has been linked to spatial summation (D. H. Arnold, M. Marinovic, D. Whitney, 2014). In the previous paradigms, eyes were always fixated on a steady fixation. Here, we investigated this in the presence of smooth pursuit eye movement. In different conditions, the target (a luminance-modulated sinusoidal grating with a spatial frequency of 1 cpd, drifting at a speed of 5 deg/sec) was presented inside a rectangular window either 1deg above or below of a static fixation spot or moved horizontally (11 deg/sec) across the screen together with the fixation. Abutting the target was a high-contrast inducer grating drifting at the same speed. Inducers were presented in both sides of the fixation. In a 2-AFC task, subjects reported whether the target appeared alongside the above or below inducer. The results of our control condition, where eyes were fixated on a steady fixation, were similar to the findings of Arnold et al such that the thresholds in the 0 deg-phase-difference condition between the target and the inducer were as low as in the no-inducer baseline, whereas they were significantly higher in the 180 deg-phase-difference condition. Moreover, there was a trend of phase modulation being higher for the targets in the leading position than those in the trailing position. In the main experiment, where participants were performing a smooth pursuit eye movement while performing the task, the phase modulation was significant only when the target was on the leading position with respect to both eye movement and inducer motion. These results indicate that underlying the effects of phase modulation and eye movement may be different mechanisms.

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Poster Session I > Eye Movements: Perception, neural mechanisms > Poster I43

Theoretical evidence for an active model of edge sensitivity in human lightness perception

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Multiscale spatial filtering models account for a variety of phenomena in human lightness perception, such as Simultaneous Contrast and White's illusion, by combining outputs of oriented filters at multiple scales. However, it was shown that these models were unable to account for spatial frequency specific effects of narrowband noise on White's illusion (Betz, Shapley, Wichmann, & Maertens, 2015). This data showed that noise between 1-5 cpd specifically interfered with White's illusion. The effect did not scale proportionally with stimulus size. To us this suggests a crucial role of luminance edges in lightness perception as proposed by edge-integration models. In these models, lightness is computed by integrating contrast signals at luminance discontinuities (=edges) across space. Here we propose an edge-sensitive mechanism in which edge signals emerge from multiscale filter responses to an actively-sampled, time-varying input signal such as it would result from fixational eye movements (FEMs). Instead of extracting edges explicitly from edge-detectors, our computational approach produces edge signals as a byproduct of using unoriented multiscale filters on these time-varying inputs. We show in simulations that edge signals actively derived from FEMs are most strongly affected by noise between 1-5 cpd. This is consistent with the data of Betz et al. (2015). Furthermore, we find that a

broader range of filter scales is sensitive to edge information when using this approach as compared to extracting edges explicitly from edge detectors. We take this as initial evidence that incorporating FEMs in multiscale spatial filtering models may be a fruitful way to model edge sensitivity in human lightness perception. Our results support the proposal that FEMs are part of a dynamic strategy of the visual system to actively encode visual information in space and time.

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Lawful kinematics of saccades predict the limits of high-speed motion perception

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The massive motion that saccades impose on the retinal image routinely goes unseen. Here we advance a novel account of this perceptual omission, based on object motion perception studied during fixation. We show that the boundaries of object motion visibility emulate lawful kinematics of saccades—the tight relation between their amplitude and peak velocity known as the ‘main sequence’. In a series of experiments, we investigated the visibility of the motion of a full-contrast Gabor stimulus. On each trial, the stimulus appeared at one screen location, rapidly moved to a new location (at near-saccadic speed), and then disappeared again. Increasing stimulus speed qualitatively changed the percept from continuous to apparent motion, a transition that we quantified by having observers report a small curvature added to the motion trajectory (only visible for continuous motion). For each movement amplitude, the resulting speed threshold increased systematically with the movement amplitude, closely matching the main-sequence relationship for saccades. This result suggests that the amplitude of a stimulus’ motion, in combination with its velocity, controls perceptual omission of motion. To investigate if amplitude information—rather than some form of motion integration—was instrumental for the amplitude-dependence of omission, we varied the duration for which the stimulus was visible before and after its movement (0, 12.5, 50, or 200 ms). When the stimulus started to move as soon as it appeared on the screen and disappeared as soon as it reached its final position (0 ms condition), motion visibility was directly proportional to movement speed, and independent of movement amplitude. Providing amplitude information—with as little as 12.5 ms of pre- and post-movement stimulus duration—fully restored the initial pattern of results that visibility was directly proportional to the main sequence. We argue that the kinematics of saccades entail systematic sensory consequences that the visual system exploits to effectuate perceptual omission.

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Initiating the tracking of a target moving across the central visual field: a study in macaque monkey

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Triggering a saccade toward a static visual target depends upon spatial attributes. The smaller the target eccentricity (or saccade amplitude), the longer the latency. According to the equilibrium hypothesis, a goal directed eye movement is not initiated as long as the visuo-oculomotor system is within a mode where opposing commands counterbalance each other. We further investigated this dependence in macaques trained to track a target which, after moving toward the central visual field, moved away in the same direction. During such conditions, the target eccentricity diminishes during the centripetal motion and increases during the centrifugal portion. After fixating a central static target for a variable interval, a peripheral target appeared at 8 possible locations and moved toward the symmetrical location in the opposite

visual field. The monkey was rewarded for tracking it until its disappearance. For each trial, the target path was pseudo-randomly selected and its speed was non constant: the target decelerated from a maximum speed (40, 60 or 80°/s) to rest. The different target decelerations were tested during different blocks of trials. After target onset, the eye often drifted in the same direction as the target motion. The glissade amplitude increased with time. For the slowest target, the glissade started before the target crossed the center of the display. By contrast, it started after the central crossing when the target moved faster. Saccade latency increased while the centripetal target approached gaze direction. As the target became centrifugal, the saccade latency increased much more. For the fastest target, centrifugal saccades were predominant and exhibited an opposite tendency insofar as the small target eccentricities (small saccades) were no longer associated with the longest latencies. More generally, our study confirms that saccade triggering does not come down to a temporal process which is free from spatial attributes of gaze or target.

Poster Session I > Eye Movements: Perception, neural mechanisms > Poster I46

The Effect of Target Motion and Smooth Pursuit Eye Movement on the Visibility of Isoluminant Target Gratings

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Contrast sensitivity to brief flickering chromatic stimuli is higher during pursuit than during fixation (A. C. Schütz, D. I. Braun, D. Kerzel, K. R. Gegenfurtner, 2008). Here, in the first experiment, we tested this using drifting stimuli and measured the detection thresholds as a function of the congruency between the directions of eye movement and grating motion. In different conditions, the target (a magenta-cyan isoluminant sinusoidal grating, 1 cpd, drifting at a speed of 4 deg/sec) was presented inside a rectangular window with 1deg eccentricity to the static fixation spot or moved horizontally (9 deg/sec) across the screen together with the fixation. In a 2-AFC task, subjects reported whether the target appeared above or below the fixation. Similar to Schütz et al, visual sensitivity to dynamic isoluminant gratings was enhanced in the presence of pursuit. Furthermore, thresholds during pursuit were 25% lower than those during fixation when eyes and sinusoidal grating moved incongruently, as opposed to when they moved congruently (15% drop from the baseline). In a second experiment, we investigated the presence of an inducer stimulus on the target visibility. Visibility of dynamic sinusoidal target patterns leading the inducer, containing phase-congruent motion are high, indicating a reduction in discrimination thresholds compared to those in phase-incongruent-motion condition (N. W. Roach, P. V. McGraw, A. Johnston, 2011). Roach et al studied predictive mechanisms with achromatic gratings while eyes were steady. Here, we aimed to investigate this phenomenon using isoluminant gratings and in the presence of pursuit eye movements. We found that the phase modulation demonstrated for the leading targets is absent at isoluminance. Furthermore, thresholds are lower for the trailing targets compared to the leading targets in the presence of pursuit. These findings suggest separate mechanisms for the effects of eye movement and inducer motion on the visibility of isoluminant stimuli.

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Poster Session I > Eye Movements: Perception, neural mechanisms > Poster I47

Classifying binary decision-outcomes from pupil dilation: A random forest approach

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Pupil dilation may reveal the outcomes of binary decisions. Hereby, pupils dilate stronger for stimuli that are deemed targets by the beholder than for distractors. Respective findings are built on average pupil dynamics, aggregated over multiple trials and participants rather than on single trials. Further, the reported differences between targets and distractors in pupil size hugely vary between investigations, likely due to differences in the proportion of target to distractor stimuli. Previous research addressed the principle question using machine-learning techniques. The respective investigations did not control for effects of motor execution on pupil size, largely ignored possible effects of stimulus probability, and used generally less controlled settings with uncontrolled gaze position. We reanalyzed pupil sizes of n = 18444 trials, lasting 3 s each, gathered from n = 69 participants to classify binary decision-outcomes with a random forest classification approach. Participants were presented with either targets or distractors at a likelihood of 25%, 50%, or 75% in blocks. In half of the trials, participants had to indicate whether the respective presented letter was a target overtly via key press. Results show best classification performances for targets that were rare (25%) relative to distractors with an AUC of 0.75, while AUC was 0.69 at equiprobability and 0.58 if targets were more frequent than distractors with 0.50 as baseline chance level. Classification was better without key press, reaching up to an AUC of 0.77 when targets were rare (25%). The first derivative of pupil size changes provided the most informative features, all of which could be derived within the first second of the trials, suggesting that a successful classification could be reached relatively fast. These results are useful for research where intention cannot be communicated overtly. We further discuss possibilities for applications building on pupil-based intention classification.

Poster Session I > Eye Movements: Perception, neural mechanisms > Poster I48

Unfold.jl: Leveraging Julia to fit fast and flexible Linear(Mixed)Models to EEG data with optional overlap correction or spline regression

View Poster | Visit me in Gather.Town Manatee Room on Wednesday 8:00 am - 10:00 am EDT

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Electrophysiological research with event-related brain potentials (ERPs) in vision is increasingly moving from simple, strictly orthogonal stimulation paradigms towards complex, quasi-experimental designs and naturalistic situations that involve fast, multisensory stimulation and complex motor behavior. Previously, we described a framework to model (potentially confounding) ERP overlap and to statistically control for biased covariate-distributions. Examples for such situations can be found in classical reaction-time experiments, where stimulus and response ERPs overlap in time. Further in combined EEG/eye-tracking experiments during natural vision where fixation-ERPs overlap with each other, in fast multisensory stimulation experiments, movie-watching or in mobile brain/body imaging studies. Here, we introduce Unfold.jl, a reimplementation of our MatLab unfold toolbox in the open-source programming language Julia. Unfold.jl supports both, mass univariate linear models and time-regression (deconvolution) models. It further allows to fit factorial designs and continuous regressors (with or without spline-regression), estimating all of these as either linear models or linear mixed models (LMMs), with LMMs being one of the main advantages over the MatLab implementation. All models can be easily constructed using the popular formula-interface. Wrappers for Python and R exist. Due to an improved modular design of the toolbox we now support custom basis functions, for example HRF-, SCR- or pupil basis functions which complement the default non-structured FIR basis functions. This allows the user to easily apply the same analysis framework to other timeseries signals. The open-source toolbox with documentation and unit-tests is freely available at https://github.com/unfoldtoolbox/unfold.jl.

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Poster Session I > Eye Movements: Perception, neural mechanisms > Poster I49

Midbrain superior colliculus motor bursts do not dictate saccade kinematics

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The primate superior colliculus (SC) is critical for saccade generation. Its neurons are organized topographically such that the site of neural activation defines the desired size and direction of an executed movement. However, in addition to this spatial code, SC neurons also exhibit a strong motor burst that is tightly synchronized with saccade onset. The functional role of this motor burst, and particularly its stereotypical temporal evolution, has long intrigued oculomotor physiologists. A well-accepted hypothesis is that motor bursts are critical for transforming the SC spatial code into a temporal command for realizing the millisecond-by-millisecond movement kinematics; thus, the site of SC activity

dictates saccade dimensions, but the motor bursts define kinematics (e.g. saccade peak velocity). Here, I was motivated by recent observations that SC motor bursts in the upper visual field representation are significantly weaker than bursts in the lower visual field representation (Hafed and Chen, 2016). Moreover, seemingly more lower visual field SC neurons are active for downward saccades than upper visual field neurons are active for upward saccades (due to response field size differences). If SC motor bursts dictate saccade kinematics, then downward saccades should be dramatically different from upward saccades in kinematics. I analyzed thousands of visually-guided, delayed visually-guided, and memory-guided saccades from two monkeys; the saccades ranged in size from microsaccades to approximately 15 deg saccades, and they had different directions. I classified movements as being directed towards upper or lower visual field locations. Even though upper visual field saccades had significantly faster reaction times than lower visual field saccades in all tasks (as expected), kinematics (evidenced by main sequence plots of peak velocity versus amplitude) were very similar. These results suggest that SC motor bursts do not necessarily dictate saccade kinematics, and they motivate future research into the functional role of SC saccade-related activity.

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Poster Session I > Eye Movements: Perception, neural mechanisms > Poster I50

More and faster secondary saccades after a lesion to the posterior parietal cortex

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Background: The posterior parietal cortex (PPC) was thought to be indispensable for processing extraretinal signals to generate accurate secondary saccades (S2). However, recent studies show that patients with chronic PPC lesions use some form of extraretinal signals to perform S2s or to perform the intrasaccadic displacement task. Hence, a PPC lesion might result in less reliable processing of extraretinal signals, instead of completely abolishing it. In this study, we investigated whether this lesser extraretinal reliability manifests itself as a decreased or delayed S2 initiation. Method: Patients and healthy controls performed a saccadic localization task (prosaccades) in two conditions. In one condition the target remained visible after the execution of the primary saccade (S1), in the other condition, the target was removed from the screen for 1 second. In the second condition, but not the first, accurate corrections (i.e. S2 generation) of S1 error relied more on extraretinal signals. S2 generation was analysed using linear mixed-effects modelling. Additive hazards analyses were performed to assess the time course of S2 generation within groups. Results: Although patients demonstrated slower S1 execution and lower S1 amplitudes than controls, they were able to generate S2s in order to overcome S1 inaccuracy, both when the target remained visible and when it was removed after S1. Furthermore, patients showed more and seemingly earlier S2 generation. Conclusion: These findings support the hypothesis that a PPC lesion does not abolish the use of extraretinal signals. Although patients' behaviour differed from that of healthy controls and could therefore be regarded as deviant, we suggest that the observed change in oculomotor behaviour after a PPC lesion reflects an adjustment to increased sensorimotor noise. This implies that more and faster S2s could be optimal given the PPC lesion.

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Fixation Related Microsaccade Inhibition in Free-Viewing and its Dependence on Stimulus Saliency

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Microsaccades (MS, <1dva) that occur during fixation were studied extensively in response to transient stimuli, while participants had to fixate their gaze. In these conditions, MS are typically inhibited in response to transient stimulus presentation (Oculomotor Inhibition, OMI), and later released with a latency that depends on stimulus saliency, attention and expectations. However, it is yet unknown whether the same holds for free viewing, i.e. that MS obey a similar pattern of inhibition in response to the visual transient induced by large saccades in natural vision. Here, we investigated the hypothesis that every saccade provides a new stimulus that should result in OMI that depends on the post-saccadic image in a similar (but not necessarily identical) way as in flashed presentation. Participants (N=16), freely inspected static displays of randomly oriented Gabor texture images, with varied Contrast and Spatial Frequency (SF) for periods of 10sec each. Eye tracking recordings were divided into epochs triggered by saccade landing (>1dva) and MS reaction time (latency relative to fixation onset) was computed (msRT). We found that the msRT in free viewing was shorter for more salient stimuli (higher contrast or lower SF), as previously found for flashed stimuli. Moreover, we found that the msRT decreased across successive saccades, but only for the higher contrast, suggesting contrast dependent adaptation in free viewing. We also found a positive correlation between msRT and saccade size for high SF but not for low SF. Our results indicate that visual stimulus-dependent inhibition of microsaccades generalizes to free viewing, with latencies that resembles the pattern of inhibition in response to flashed-stimuli.

Poster Session I > Eye Movements: Perception, neural mechanisms > Poster I52

Contrast Sensitivity of Vertical Vergence Eye Alignment

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Purpose: The purpose of the study was to measure the response of vertical vergence eye movement to bandpass filtered noise of various spatial frequencies and contrasts. The results of our previous experiment in which we measured the contrast sensitivities using vertical vergence response to sine-wave gratings suggested that vertical vergence responses were robust for middle spatial frequencies (0.5 to 4 cycles per degree). However, the responses to higher and lower spatial frequencies were weaker. The weak responses at higher spatial frequencies could have been due to matching ambiguity of the gratings in the two eyes. So, to eliminate this ambiguity we used bandpass filtered noise as the stimulus to measure the contrast sensitivity of vertical vergence eye alignment. Methods: Subjects were 2 adults with normal vision. A Dual Purkinje image eye tracker was used for eye tracking. Vertical vergence was measured in response to full-screen bandpass filtered noise patterns of all orientations with one-octave bandwidth. A block of trials comprised combinations of 8 contrasts [0%, 1%, 2%,4%,8%,16%,32%,64%] and 8 spatial frequencies [0.125, 0.25, 0.50, 1, 2, 4, 8 ,16 cpd] presented in shuffled order. Various Oculometric functions (AUC, Percent Correct, Weibull fit, Vergence amplitudes) were created to determine the oculometric CSFs. The psychophysical CSF was obtained with a 2AFC staircase method for the same spatial frequencies using bandpass filtered noise patterns as stimuli. Results: Vertical vergence responses were robust for middle spatial frequencies. The responses for higher spatial frequencies were weaker or absent, similar to the results with sine-wave gratings. Conclusion: The results of this study suggest that matching ambiguity was not the primary limiting factor in the response of vertical vergence at higher spatial frequencies, despite being easily detected psychophysically. Further research is needed to understand why vertical vergence does not show a response at higher spatial frequencies.

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Linking individual differences in fixational eye movements and visual acuity

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During fixation, ocular drift continually shifts the retinal projection of objects across the foveola, where visual acuity is highest. Previous research showed that the spatiotemporal modulations introduced by ocular drift enhance high spatial frequencies in a way that depends on drift characteristics; the smaller the drift, the higher the spatial frequencies enhanced. Based on these findings, we hypothesized that differences in high acuity thresholds across observers are linked to individual variations of ocular drift. To investigate this issue, we measured visual acuity thresholds of 10 observers while monitoring ocular drift with a high-precision eye-tracker. Subjects performed a 4AFC discrimination task. Stimuli consisted of single digits, which size was adjusted using an adaptive procedure (width ranging from 0.4' to 4.5'). To quantify the amount of retinal motion generated by ocular drift, we calculated its diffusion coefficient, which defines how rapidly the line of sight moves away from its current location. Ocular drift diffusion coefficient varied by a factor of four across the tested observers (average; 14 ± 5 arcmin2/second). As a result, the range of spatial frequencies being enhanced by drift varied between 10 cpd to 60 cpd across individuals. Consistent with our prediction, we found a significant correlation ($r = 0.73$, $p = 0.02$) between acuity thresholds and drift diffusion coefficients across subjects: the higher the visual acuity, the lower the drift diffusion coefficient. The same correlation was observed when drift was measured independently from the task, during fixation on a marker. Importantly, the spatial frequencies enhanced by drift matched with the most informative frequencies for discriminating among digits in the task. These findings show that differences in ocular drifts are related to individual variability in acuity. They support the idea that drift luminance modulations impact acuity and suggest that acuity could be inferred by the characteristics of eye drifts.

Acknowledgements: (MP) NIH R01 EY029788-01, (JI) F31EY029565

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Rapid and persistent visual adaptation transfers across saccades

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Neurons in the visual cortex quickly adapt to constant visual stimulation, which should lead to perceptual fading within tens of milliseconds. However, perceptual fading is rarely observed in natural vision, which may be due to eye movements refreshing retinal input. Recently it has been suggested that the amplitudes of large saccadic eye movements are scaled to maximally decorrelate the pre- and postsaccadic inputs and thus serve to annul perceptual fading (Samonds, Geisler, & Priebe, 2018). Here we investigated whether short-term adaptation within natural fixation durations can survive a saccade and influence perception at all. To investigate rapid adaptation effects on perception, we developed a paradigm in which participants executed a horizontal saccade along a gap between two vertically oriented luminance gratings each with a different spatial frequency chosen to either correlate or anticorrelate pre- and postsaccadic retinal inputs given the saccade amplitude. The correlated grating resulted in the same retinal input before and after the saccade; the anticorrelated grating resulted in an inverted contrast polarity postsaccadically. Participants indicated which grating had the higher contrast after the saccade. Measuring the point of subjective equality (PSE) over various postsaccadic contrast differences between the gratings, we found large and reliable PSE shifts indicating lower perceived contrast of the correlated grating. Varying presaccadic adaptation duration revealed an effect after a few 100 milliseconds of adaptation. Delaying the postsaccadic stimulus onset revealed that the effect survived even our longest delay of 1.6 seconds. Our results show that adaptation can be strong, rapid, and persistent enough to attenuate perceived contrast within natural fixation durations, and that this effect can outlast a large saccade despite the strong disruption of visual input during the saccade. Our findings support the assumption that optimal saccade amplitudes serve as means to decorrelate pre- and postsaccadic inputs and to counteract perceptual fading.

Acknowledgements: This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 676786).

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Saccades and pupil size are driven by a common arousal-related input

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Introduction: Pupil size is commonly used to estimate arousal by assuming pupil size is a linear transformation of task events. However, this assumption has not been tested. Methods / Results: Both pupil size and saccade rate entrain to task timing, but only pupil size is amplitude-modulated by arousal. We propose that a noisy common input drives both saccades and pupil size. We formalize this hypothesis in a linear-nonlinear model in which pupil size is the output of a low-pass filter acting on the noisy common input and a saccade is generated each time this same input crosses a threshold. Unlike previous work, we do not assume that the input to the pupil is simply the timing of task events, but rather that it has more complex dynamics. Ten observers performed an orientation discrimination task that varied in difficulty in alternate runs (75 trials/run; 4 s/trial). We estimated the dynamics of the common input as well as its amplitude. The amplitude was associated with arousal, i.e., significantly modulated by task difficulty, accuracy, and reaction time. Our model predicted task-evoked pupil responses equally well for easy and difficult trials, with 81% variance explained overall. In a second experiment, we ran 2 and 4 s trials in separate blocks. Our model's single free parameter generalized between the two timings whereas previous (linear) models failed to (reduction in R^2 between in-and out-of-sample fits: 2.5x larger for linear model vs. our model). Discussion: Saccades and pupil size share a common input, consistent with recent reports that electrical stimulation of superior colliculus neurons above or below the threshold of saccade generation evokes a pupil response (Joshi et al., 2016; Wang & Munoz, 2020). Our model formalizes this observation. We offer a novel algorithm, based on this model, yielding arousal estimates that are accurate and generalizable.

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How fixation durations are related to the functional visual field and target guidance

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Concepts like the span of the effective stimulus or the functional visual field (FVF) have been increasingly investigated in recent visual search and eye tracking studies. In particular, the FVF has been used to explain how many fixations are necessary to find a target and why observers sometimes miss a target even though their gaze fell close to the target position. FVF studies usually focus on the number of fixations or on saccade amplitude. In contrast, fixation durations received very little attention in the literature and are often assumed not to vary in a meaningful manner as a function of the current visual input. In the present study, we assume that the presence of the target within the FVF can speed saccade planning and that this registers in shorter fixation durations before a saccade is made to the target. We conducted a free viewing search experiment where participants had to find a specific target shape. Results showed shorter fixation durations for the last distractor fixation before a saccade was directed to the target. Fixation durations are not shorter when target discriminability is low, suggesting that the subsequent target saccade is not guided by target information. Moreover, shorter fixation durations only occur when the fixation is within a specific distance to the target. We discuss whether fixation durations are only shortened by facilitated saccade planning when the target falls within the functional visual field. If so, fixation durations could be used to estimate the size of the functional visual field or the span of the effective stimulus.

Acknowledgements: This study was supported by Deutsche Forschungsgemeinschaft (ER 962/1-1).

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Fixation-related potentials in total darkness

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Although saccade- and fixation-related potentials (SRPs/FRPs) in the EEG are increasingly used as a tool in vision research, basic properties of these neural responses are still poorly understood. In particular, it is unclear to what degree nonvisual processes (e.g., from a corollary discharge) also contribute to eye movement-related activity measurable at the scalp. Likely due to technical and data-analytical limitations, older EEG studies on this issue have yielded inconsistent results, with the majority of papers reporting that SRPs/FRPs disappear entirely when the visual field is dark or featureless. The present work aimed to more systematically explore nonvisual contributions to the SRP and FRP waveforms generated by spontaneous saccades. EEG recordings were combined with long-wavelength infrared eye-tracking while participants searched for an occasionally appearing low-luminance target stimulus either in total darkness or while viewing natural scenes. Nonlinear deconvolution modelling (Dimigen & Ehinger, 2021) was used to control for overlapping potentials and to estimate responses in the time domain. As a key finding, we observed significant peri- and post-saccadic activity over visual cortex in total darkness, which peaked as a negative potential at occipital electrode Oz about 110 ms after saccade onset (or 70 ms after fixation onset). Topographically, this nonvisual response was polarity-reversed compared to the surface-positive postsaccadic lambda response (P1) seen with visual stimulation. This earlier nonvisual effect was followed by a positive potential peaking as late as 350 ms after saccade onset. Interestingly, nonvisual effects scaled nonlinearly with saccade size, suggesting that the well-established nonlinear relationship between saccade size and lambda response (P1) may be at least partially explained by nonvisual mechanisms. In summary, we observed clear modulating effects of saccade execution on early visual areas recordable in the scalp EEG. Frequency-domain and phase-locking analyses will be presented in an attempt to elucidate the functional relevance of these effects.

Motion Perception 2

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The weights of internal and external motion driving the double-drift illusion depend on the external speed

View Poster | Visit me in Gather.Town Manatee Room on Wednesday 8:00 am - 10:00 am EDT

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The double-drift illusion, also known as the infinite regress and curveball illusion, is a particularly dramatic example of a motion-induced position shift; its combination of internal and external motion vectors of a drifting gabor produces large misperceptions of both position and direction of motion. Here, we measure the size of the illusion at 7 internal speeds combined with 6 external speeds in order to determine how internal and external velocities influence the perceived direction of the illusion. While fixating on a black fixation point, participants were instructed to report the perceived direction of the gabor. A separate VonMises distribution was fit to the distribution of directions for each of the 42 internal/external speed combinations for each session and participant individually. Our results confirm previous work (Cavanagh & Tse, 2019; Tse & Hsieh, 2006), showing that the magnitude of the illusion, as measured by the displacement of the perceived trajectory in the direction of internal motion, increases as the speed of the internal motion increases, and decreases as the speed of the external motion increases. Moreover, our results also reveal that the best fitting weights in the combination of the internal and external motions uniquely depends on the speed of the external motion. We compare vector combination models (AIC=61.9) and optimal object tracking models (AIC=268.8) and find that the former does a better job accounting for our results.

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Temporal integration window of the double-drift illusion: an immediate effect of the internal motion

View Poster | Visit me in Gather.Town Manatee Room on Wednesday 8:00 am - 10:00 am EDT

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The double-drift illusion, also referred to as the infinite regress and curveball illusion, is an extreme example of a motion-induced position shift. If the internal sign-wave grating of a Gabor patch moves orthogonally to the direction of the patch, its perceived direction may be shifted by more than 50º. This shift reflects a combination of the patch and internal motions. Question: How long does it take to combine information about the internal and external motions of the doubly drifting Gabor patch. Methods: Participants reported the direction of a moving Gabor patch in either a control condition that had no internal motion, or a double-drift condition with orthogonal internal motion presented for either 8.4, 16.8, 25.2, 33.6, 42.0 or 50.4ms (2 to 12 frames at 240 Hz refresh rate). For each condition, the patch direction ranged randomly from 0º to 351º in steps of 9º. We subtracted the actual external drift direction from the reported direction and fit a Von Mises distribution to these values, averaged across subjects. Results: Already at the shortest stimulus duration, 8.4 ms, the mean of responses for the double-drift condition differs significantly from zero (62º, p<.0001), with significant clustering around that value (kappa= .51, p<.00001). At the same duration, the control responses did not differ significantly from zero (24º, p = .16) but still clustered significantly (kappa = .51, p<.00001). At longer durations, the double-drift responses remained in the range of 45º to 60º while the control responses approached 0º. Thus, even at the shortest presentation duration, the internal drift already drives perceptual reports as much as it does at longer durations. Conclusion: The illusory direction appears to be in place as soon as the double-drift stimulus appears.

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Exploring common mechanisms of visual motion prediction

View Poster | Play Video | Visit me in Gather.Town Manatee Room on Wednesday 8:00 am - 10:00 am EDT

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Visual motion prediction is the ability of visual system to predict spatial and temporal properties of moving stimuli (e.g. where and when a moving ball will be). Recent studies have suggested that one way of achieving visual prediction is to predict forward spatial pattern based on past input motion information. Here, four tasks related to spatial perception changes caused by motion were studied together within the framework of visual prediction: Motion Induced Spatial Conflict (MISC), the Time Course of the De Valois Effect (TCDVE), Motion Adaptation Induced Spatial Shift (MAISS), and a Smooth Motion Threshold (SMT) task. We used correlation analysis to investigate whether any performance relationship could be found among those tasks. The result showed that there was a significant moderate positive relationship (Spearman's $r = 0.5$, $p = 0.01$) between performance on the MISC and TCDVE tasks. There was no significant relationship between any other pair of tasks. This result suggested that only MISC and TCDVE among four tasks can be clustered together, implying a common mechanism of visual prediction.

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Position shifts following motion aftereffects in non-static translating stimuli result in angled trajectories

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After adapting to a moving pattern, subsequently viewed static patterns appear to move in the direction opposite to adapting motion (Wohlgemuth, 1911). Motion aftereffects (MAE) can also produce shifts in the perceived spatial position of static test stimuli (Snowden, 1998). Here, we extend these results by showing how the MAE shifts the position of non-static, translating stimuli. Participants adapted to a large sine-wave grating, presented in their peripheral vision, which drifted vertically either upwards or downwards for 5 seconds. This adapting stimulus was then replaced by a small Gabor patch that moved horizontally for 1 second. Participants then reported the angle of the patch's motion. This procedure was repeated 6 times per trial, each time following 5 seconds of adaptation, allowing us to measure changes in the perceived angle after various adaptation durations. In all cases, the perceived angle of the Gabor's drift deviated from its actual horizontal trajectory in the direction opposite to adapting motion. Our results suggest that the MAE causes positional shifts in a non-static, translating stimulus and that these offsets accumulate over the 1 second test presentation, generating a linear, angled trajectory. The angle of offset from horizontal also increased significantly with adaptation duration, from 9.5° following 5 seconds of adaptation, to 15° following 30 seconds of adaptation, equivalent to a vertical position shift of 0.96 dva across test presentation. This is larger than the 0.5 dva shift reported by Snowden (1998) under relatively similar adaptation conditions but with a static test. The angled trajectories we report here reflect some combination of the Gabor's actual external motion vector and a vector opposite to the adapting stimulus, the MAE. The mechanism underlying this combination of motion vectors may be similar to that observed in the double-drift illusion (Cavanagh & Tse, 2019; Tse & Hsieh, 2006).

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The Orbiting Circles Illusion: Induced changes in the length and direction of motion trajectory

View Poster | Visit me in Gather.Town Manatee Room on Wednesday 8:00 am - 10:00 am EDT

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We introduce a novel motion illusion that we call the Orbiting Circles Illusion. The illusion uses relative motion cues to induce changes in the perceived trajectory of a continuously moving object. A central target circle continuously moves along a circular path in an apparent orbit around a central point. Concurrently, a set of inducers (similar to those in the Ebbinghaus configuration) surround the central target circle, each moving along their own local orbits. Perceptually, the relative motion of the inducers alters the apparent trajectory of the central circle. The specific perception depends on the speed and position of the inducers relative to the target. The illusion is apparent under peripheral fixation conditions,

suggesting that small eye movements are not necessary to alter the perceived position of the target. A central fixation point or a static object near the target abolishes the illusion. Overall, the illusion shares many similarities with frame-induced position shifts (Cavanagh, Wexler, & Anstis, 2020, Journal of Vision, 20(11), 607-607). Additionally, it reveals two striking effects. First, the circular motion of the target can appear strictly linear in nature. Second, the length of the linear trajectory can appear much greater than the physical displacement of the target. The former effect has implications for the coding of curvature on motion trajectories and the latter effect has implications for the coding of position that have been recently studied using paradigms such as the flash drag, flash lag, and double-drift. Here, we demonstrate a number of factors, such as speed, positioning, and feature similarity, that affect the magnitude of the Orbiting Circles Illusion.

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Eccentricity Dependence of Motion Induced Position Shifts Revealed by Continuous Motion Nulling

View Poster | Visit me in Gather.Town Manatee Room on Wednesday 8:00 am - 10:00 am EDT

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When a Gabor patch is composed of a drifting grating within a stationary envelope, the Gabor appears to change position – a motion-induced position shift (MIPS, a.k.a curveball or double drift illusion). MIPS can be used to create dramatic motion illusions of global form (http://illusionoftheyear.com/2016/06/motion-integration-unleashed-new-tricks-for-an-old-dog/), but is tedious to study parametrically. Here, we used a motion-nulling variant of a tracking task, in which observers attempted to keep a global form, 16 Gabor patches in a ring, centered while the envelopes and carrier were perturbed by a 2D Brownian walk. In the 'zebra' (control) condition, the carriers had a fixed phase relative to the envelop, so the carrier and envelopes moved as one. In the MIPS or 'cuttlefish condition, the carriers were driven in a horizontal random phase walk while the envelope positions were driven in an independent vertical walk; this produced a powerful illusion of the ring doing a 2D walk, despite moving only vertically. We varied the size of the global ring (spatial frequency scaled per V1 RF size). An advantage of the nulling task is that the observers keep the ring approximately centered, so ring diameter is also stimulus eccentricity. In the zebra condition, tracking performance decreased with eccentricity. In the cuttlefish condition, performance in the vertical (envelope) direction also decreased with eccentricity. In the horizontal direction however, tracking responses increased with eccentricity. Therefore, the subjects nulled the local phase walk (MIPS) as though it were global motion, especially in the periphery. More generally, our results indicate that this motion nulling paradigm is a powerful tool for studying motion perception in active observers while allowing control over where the stimulus is in the visual field. This paves the way for extending continuous tracking tasks into neurophysiology in awake, behaving non-human primates.

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Idiosyncratic preferences in translational and rotational motion transparency

View Poster | Visit me in Gather.Town Manatee Room on Wednesday 8:00 am - 10:00 am EDT

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Previous studies reported idiosyncratic direction preferences in motion transparency depth rivalry (Mamassian & Wallace, 2010; Schütz, 2014; Schütz & Mamassian, 2016), such that observers are more likely to perceive a certain motion direction in front. Here we investigated if such idiosyncratic direction preferences occur also with more complex motion types at higher levels of motion processing, such as rotation. We presented two overlapping dot clouds with opposite contrast polarity in a stationary circular aperture. In translational motion, the dot clouds were moving along a straight path in opposite directions. In rotational motion, one dot cloud was rotating clockwise and counter-clockwise each. Participants had to report the color of the dot cloud they perceived in front. In Experiment 1, rotational motion was presented inside a full circular aperture or only in a sector with varying angular size and location. In Experiment 2, we tested a mixed condition, with one dot cloud of translational and of rotational motion each. In both experiments, there were idiosyncratic directional preferences in transparent motion and, more interestingly, also in rotational motion within the full circular aperture. With smaller sectors in Experiment 1, perception depended on both the rotational and the translational direction preference, and the impact of the rotational compared to the translational preference increased with increasing sector size. This suggests that there is a transition from translational to rotational motion preference as more of the complex rotational motion field is visible. In the mixed condition of Experiment 2, rotational motion was preferred over translational motion in general, even when there were strong directional preferences in translational motion. These findings show that idiosyncratic direction preferences can occur at all levels of motion processing and that there are also preferences between different types of motion that are processed at different levels of the hierarchy.

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Paradoxical frame stabilization for flashed but not continuous probes

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Moving frames have previously been shown to produce large displacements in the perceived location of flashed probes (Cavanagh, Anstis, & Wexler, VSS 2020). Here the moving frame's effect on flashed probes is compared to its effect on a continuously moving probe. In the flashed case, the first flash was presented before and the second probe after the frame's motion. The results showed that across a 22° range of offsets between the probes, their perceived separation always discounted the frame's motion: the perceived positions were the locations each probe had in the frame when flashed, but seen as if the frame were stationary. That included the case where the two probes were far apart on the screen but at the same location in the frame. Here the probes were perceived at the same location in the world despite their 10° physical separation on the screen. This simulates the conditions of eye movements where an object is at the same position in the visual scene before and after the movement and do not appear to have moved despite the large displacement on the retina. We also tested a continuous motion condition where a single probe moved continuously up and down while the frame moved left and right. This is the classic stimulus for induced motion (Wallach, Bacon, & Schulman, 1978) and the results were very different from those with the flashed probes. The apparent direction of the probe was significantly influenced by the frame, but by only about 1/5th the amount seen for the flashed probes. It is likely that the continued presence of the probe during the frame's motion provided evidence of its physical path that reduced the frame's effect compared to that seen for the flashed probes.

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The effect of a moving reference frame depends on its perceived not physical motion

View Poster | Visit me in Gather.Town Manatee Room on Wednesday 8:00 am - 10:00 am EDT

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When an object is surrounded by a moving frame or background, an illusory motion is induced into the object in the direction opposite to the motion of the reference frame (e.g. Duncker, 1929). For instance, a target moving vertically inside a horizontally moving frame appears to move obliquely (induced motion; Wallach, et al., 1978). Here we investigated whether illusory motion can act as a reference, specifically, whether the effect of the frame depends on its physical or its perceived path. To this end, we used the double-drift stimulus (Lisi & Cavanagh, 2015; aka, curveball illusion: Shapiro et al., 2010; infinite regress illusion: Hsieh and Tse, 2006) which provides an illusory direction of motion that can deviate from its veridical path by as much as ~50 dva (Lisi and Cavanagh, 2015). We presented 4 Gabors that formed the corners of a virtual square, all with vertical external motion and all with the same, horizontal direction of internal motion. When viewed in the periphery, the double-drift "square" appeared to move on an illusory oblique path. A probe spot with no internal drift was also presented inside the frame moving vertically in phase with the double-drifts' external motion. Participants reported that the probe's motion appeared to be oblique in the direction opposite to the frame's illusory direction. In a second condition, the internal drift component of the double-drift stimuli was turned off and the illusory direction was extinguished. In this case, the probe followed its physical (vertical) path. In conclusion, the effect of the moving frame is determined by its consciously experienced motion rather than its physical motion.

Acknowledgements: This material is based upon work supported by the National Science Foundation under Grant # 1632738.

High phi as a probe of global motion processing

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In 2013 Wexler and his colleagues demonstrated a visually remarkable phenomenon they called high phi. When a rotating motion pattern (the inducer) is abruptly replaced by a non-coherent motion, an illusory jump is perceived. The illusory jump is characterized by its large amplitude, its brevity, and its direction which depends on the inducer duration (short inducer durations leading to jumps in the same direction as the inducer, while longer durations leading to jumps in the opposite direction). Here, across a series of experiments, we investigated the potential relationship of this effect with 3D global motion (optic flow) processing. We first established that the high-phi effect works with random dots (smooth textures were used in the original demonstration), and that it works with radial motion, a different form of global motion or optic flow. Next, we investigated the global nature of the phenomenon. In a first series of experiments, we established that the high-phi effect is maintained when only a small part of the stimulus underwent inducing motion (2 opposite sectors out of 16). In a second series, by removing a sector of the inducing stimulus and using a probe to test for a high-phi effect in the empty region we established that the effect occurs in the empty, unstimulated region. These results demonstrated the global nature of the high-phi effect. However, in a final experiment we demonstrated that when inducing motion is spatially distributed, the threshold inducer duration at which the effect switches from a positive to a negative jump shifts to longer durations indicating that the perceived jump direction depends on the motion duration in a locality. These results suggested that the high-phi effect is not due to global motion processing but rather it results from earlier, local effects that lead to global effects.

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Sex differences in visual processing: Does it relate to other cognition or behaviors?

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Prior research has shown sex differences in various visual perception tasks (Shaqiri, et al., 2018; Abramov, Gordon, Feldman, & Chavarga, 2012; Murray et al., 2018), but the results are heterogeneous. This challenges efforts to explain what causes the observed sex differences (Newcombe, 2020) and how sex differences in elementary vision relate to other sex-differentiated characteristics. Here, we tested 132 adult participants (102 females) on two tasks involving low-level vision where prior research had shown sex differences—a contrast sensitivity task (Abramov et al., 2012), and a motion detection task (Murray et al., 2018). In addition, we included tasks that tap other sex-differentiated characteristics (mental rotation and hobby choice), and a control task where no sex difference was expected (vocabulary size). The results showed that, relative to males, females had higher contrast sensitivity thresholds, longer motion direction detection thresholds, lower mental rotation scores, lower interest in male-typed hobbies, and greater interest in female-typed hobbies, but no differences in vocabulary size. These findings replicate prior work. In addition, we found that individual performance on both visual tasks correlated with mental rotation scores (contrast sensitivity: r=.29, p<.01; motion duration threshold: r=.28, p<.01) and hobby interests in females. Particularly, contrast sensitivity thresholds were negatively correlated with females' interest in masculine hobbies (r=.21, p<.05), while motion duration thresholds were positively correlated with females' interest in feminine hobbies (r=.20, p<.05). The two visual measures did not correlate with one another in females (r=.09, n.s.) but did correlate in males (r=.54, p<.01). The results add to findings showing sex differences in visual perception that favor males, and they provide new evidence that sex differences in vision relate

to other sex-typed characteristics. How low-level vision relates to sex differences in spatial cognition or hobby choices remains an important question for future research.

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Causality detection in the visual system is tuned to motion direction

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We perceive causality even in simple kinematic displays—a moving disk that stops next to another disk appears to launch the second disk into motion. Visual adaptation alters perceived causality in retinotopic coordinates, suggesting that causality is computed early in the visual system. Here, we used adaptation to show that causality detection is tuned to a key low-level feature of the visual event—its motion direction. Observers saw brief test events in which a peripheral disk moved swiftly towards a stationary one and, as soon as they overlapped by some amount (zero to full overlap in seven steps), the first disk stopped and the second disk started to move along the same trajectory. Observers then reported whether they perceived the first disk to pass over the stationary one (reported commonly at full overlap), or rather, to launch it into motion (common at zero overlap). We presented test events in one of two horizontal directions both before and after adaptation to causal launches presented in a narrow range around one of these two directions. To induce adaptation, we exposed participants to a stream of 320 launch events before the first adaptation test trial, topped-up with an additional stream of 16 launch events before each subsequent trial. For each observer, adaptation decreased the amount of overlap that could elicit perception of a causal launch, replicating previous findings. This negative aftereffect was strongest when the test event's motion direction matched the adapted one. The direction-specific tuning cannot be accounted for by adaptation to non-causal features of the adaptation stimulus, as no adaptation occurred after exposure to control events, designed to match the launch in as many physical properties as possible. Direction-specific adaptation to causal events demonstrates that the computation of phenomenological causality relies on low-level routines implemented at early stages in visual processing.

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Visual Prediction of Bounce Trajectories

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To catch or avoid an object it is crucial to predict its future trajectory. Here, we test how well observers can predict the landing position of a bouncing object and identify the strategies they employ to solve this task. A large database (N=100,000) of short simulations of a cube bouncing in a 3-dimensional room allows us to measure the cube's typical behavior, while its elasticity, initial orientation, position and velocity are varied. We randomly selected and rendered 240 animations from this database as stimuli. Fourteen observers saw either the first 10, 20, 30, 40, or 50 frames of each animation and had to predict where the cube would eventually come to rest. The number of remaining frames in which the cube was still moving (but that were not presented) varied between 10-107 frames. Observers responded by moving a marker to the predicted position on the floor, indicated their certainty by adjusting its radius, and then saw the remaining frames for feedback. We found that observers make systematic predictions of the cube's final position and are better than chance for predictions of up to about 60 frames. Unsurprisingly, observers were more accurate the fewer frames (and thus fewer bounces) they had to predict. For their predictions, observers took into account the final (i.e., the last visible) direction along which the cube was moving and often predicted the landing position to be in a similar direction. Thus, the closer the trajectory was to a straight line after disappearance, the more accurate they were. Furthermore, observers predicted longer paths for cubes that moved faster before they disappeared. Presumably, observers use a simplified mental simulation strategy, which—because it is physically inaccurate—accumulates errors over time and therefore produces a larger divergence from the computer-simulated landing position with a growing number of simulation steps.

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Effects of behavioural properties on the perception of collective flow

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The human visual system is great at solving complex visual problems, but the underlying mechanics often remain poorly understood. Here, we investigate one of these complex problems—the visual perception of collective flow. This type of flow is created by a body of individual agents that show both collective and individual behaviours following a coordinated set of rules (e.g., flocks of birds, schools of fish, cars on highways). Ecologically, collective flow is particularly interesting due to its high variability and wide range of occurrences in nature. There are inanimate occurrences of collective flow (e.g., shaken metallic rods, nematic fluids), microscopic occurrences (e.g., macromolecules, cells, bacteria colonies), and richer manifestations with more intelligent organisms (e.g., insects, mammals, fish, birds, humans). Furthermore, collective flow can be portrayed by very low-level visual depictions while its highly scalable organizational complexity is expected to require higher-level understanding. Because of this we anticipate collective flow research to unveil insightful bottom-up and top-down interactions. We have built a collective flow engine using existing algorithms that capture biological collective behaviour. This engine or stimuli generator adjusts its behaviour based on properties assigned to individual agents. Here we looked at the human sensitivity of three properties in particular, zone of alignment, zone of attraction, and turning rate. Using Maximum Likelihood Difference Scaling (MLDS) we started to map the perceived differences between collective flow simulations. We find that observers are sensitive to changes in the turning rate and zone of alignment. Differences in zone of attraction were harder to perceive. The varying trends of the difference scales hint towards more complex underlying interactions. Our sensitivity to these behavioural changes demonstrates that there is ecological validity for collective behavioural processing, a novel and highly underexplored field of vision research.

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Scene Perception: Cognitive processes 2

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Explicit Ensemble Perception of Temporal and Spatio-temporal Element Sequences

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Introduction: Ensemble perception is attracting increasing interest. Presented with element arrays, participants accurately report means of different array features, but are unable to report its members' features. Ensemble perception studies used spatial presentation, i.e. simultaneously presenting elements scattered on the screen. Recently, Khayat and colleagues (2018, 2019, 2020) presented temporal sequences of ensemble elements, studying implicit effects of ensemble mean and range. We now use temporal and spatio-temporal presentation, explicitly asking participants to match a test element to sequence mean, or judge presence or absence from the sequence. Methods: We presented a temporal element sequence, all at fixation or randomly scattered, asking MTurk participants to relate to circle size, line orientation, or disc brightness. Following the sequence, participants saw a single test element, and reported presence/absence of that size/orientation/brightness in the sequence (membership test), or if the test element was larger/more clockwise/brighter than the sequence mean (mean evaluation test). Results: Participants judged test elements as present in the sequence when they were at or near sequence mean, and absent when far from the mean, or outside the sequence range – for both temporal and spatio-temporal sequence presentation. They clearly perceived sequence mean and range for size/orientation/brightness features. Nevertheless, they did not differentiate between test elements that were/were not in the sequence, except for rejecting out-of-range elements. Participants were very accurate in the mean evaluation test, with accuracy increasing (near the mean) by about 5% per 3% feature change. Interestingly, there was little difference between spatio-temporal and pure temporal sequence presentation at fixation. With our parameters, evaluation of circle size was less uncertain than other features, and brightness most difficult. Conclusions: Participants are excellent at explicitly judging sequence mean and range, for size, orientation and brightness features; are blind to presence/absence of specific elements; irrespective of foveal versus scattered presentation.

Acknowledgements: Funded by a grant from the Israel Science Foundation (ISF). We thank Yuri Maximov for computer programming assistance.

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Influences of Prior Experience on Current-trial Ensemble Perception

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Introduction: Object ensembles are summarized quickly and efficiently by their summary statistics. While studies focused on extraction of current-view and current-trial statistics (i.e., short glimpses), little attention was paid to how ensemble perception is affected by prior experience (Crawford et al., 2018) and some studies were designed to avoid or eliminate influences of previous exposure to ensemble stimuli. However, statistical information about objects is learned over time, and Bayesian theories analyzed how priors influence perception. We now devised methods to directly test prior experience effects on ensemble averaging. Methods: To characterize influences of current-trial, recent-trial and long-term statistics (i.e., experimental session stimulus distribution), we measured implicit effects of these different statistics in a circle-size membership task. 100 Amazon MTurks participated. On each trial, circles of different sizes were presented in serial sequence. Then, two test circles were presented and participants chose which was present in the sequence. With this visual memory task, where it is hard to keep individual circle sizes in memory, we assume that participants unconsciously rely on ensemble statistics and choose test images closer to the ensemble mean. To differentiate influences from the current and from previous trials, in some trial blocks the 2 test circles were equally distant from the current trial sequence mean, isolating longer-term influences. Results: Participants biased membership judgements towards the ensemble mean of the current trial, when available – the largest effect found– and also towards the mean of the preceding trial sequence, when isolated. Lastly, participants also showed preferences to the longer-term (global) stimulus-distribution mean of the entire experimental session. Conclusion: Ensemble perception is influenced not only by the statistics of the set of objects presented in the current trial, but also by recently presented stimuli and by the long-term mean (prototype) which was learned and formed through the experiment.

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The effect of spatial frequency on perceiving the gist of abnormality in mammograms

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Rapid extraction of global structural regularities provides us with basic information of our visual world, the so-called gist. Scene research is divided as to whether it is low or high frequencies that are essential for driving gist signals. However, recent work has suggested that high rather than low spatial frequencies are vital for radiologists to extract the gist of abnormality from mammograms (Evans et al., 2016). Here, we investigated the effects of high-pass filtering of mammograms on detecting the gist of the abnormal. Twenty-eight radiologists viewed mammograms for 500 ms, rating their gist impression of abnormality in unaltered and filtered images. Performance on 90 no cancer, 30 obvious, 30 subtle cancer, and 30 three years prior to sign of abnormality unaltered mammograms was compared to contrast-normalized, 2nd order Butterworth high-pass filtered versions of the same (0.5, 1, 1.5 & 2 cycles per degree (cpd)).

Filtering out frequencies lower than 0.5 and 1 cpd significantly affected the radiologists' performance (ηp2=.45) with an increased performance when frequencies below 0.5 cpd were filtered out compared to both unfiltered and 1 cpd. The beneficial effect of filtering was especially pronounced for mammograms that did not have a localized signal present (ηp2=.13), with improvement from d'=0.02 for unfiltered to d'=0.71 for 0.5 filtered, staying unchanged for 1 cpd. Filtering out of frequencies below 1.5 and 2 cpd showed no discernible pattern of promoting or impeding gist extraction in general or for different conspicuities. Overall, categorization performance was higher for images with obvious cancer lesions as opposed to subtle or mammograms acquired prior to any visible actionable signs of cancer (ηp2=.59, ηp2=.78). In conclusion, our results support the idea that high frequencies can carry important information for gist extraction of abnormality, suggesting that this signal might be especially present in frequencies between 0.5 and 1 cpd.

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Perceived position stabilization depends on the moving frame's displacement: an online study

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Knowing where things are is important. Here we examine the effect of motion context, using a frame that moves back and forth, on the perceived position of probes (Cavanagh, Anstis, & Wexler, VSS 2019). When two probe dots are flashed inside the frame at the same physical location, each at one extreme of the frame's movement, a very large illusory offset is seen between the probes, roughly equal to the frame's travel. Here we examine the effects of the distance, duration, and speed of the frame's travel on the perceived spatial offset. A total of 274 York University undergraduates completed an online task (PsychoJS, hosted on Pavlovia). After screening participants for appropriate devices and self-reported understanding of the task (60), and response outliers (73), 141 remained. Reliable monitor calibration was available for about 40% of participants. The size of the stimuli in degrees of visual angle did not affect illusion strength so we combined all data. The perceived spacing approximately matched the distance the frame moved, both when varying the speed (r^2=0.97, p=.001) and the duration (r^2=0.92, p=.006) of the frame's motion. Conclusion: stimuli flashed before and after a frame's motion are seen in their coordinates relative to the frame as if the frame were stationary.

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How far away is your phone in this picture? Determining object distance and size in a 2D scene

View Poster | Visit me in Gather.Town Dolphin Room on Wednesday 8:00 am - 10:00 am EDT

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How do we judge the distance of familiar objects seen within a picture? If the physical size is known, the object's distance can be judged relative to other objects in the scene, but without such references the viewer must estimate its distance solely from their knowledge of its size. How well can we do that? Using remote testing via PAVLOVIA, participants viewed a rectangular block, scaled to the size of their personal smartphone, placed upright in a hallway scene that provided ambiguous distance information, displayed on a computer screen viewed at 50cm. In exp1 (n=74), they were given 5 sizes of block and adjusted their distances to look correct based on the known physical phone size. In a second task, they adjusted its visual size when it was placed at the same distances they had set in the first task. In exp2 (n=60), the task order was reversed, and distances were also given in meters. Participants could differentiate the distances and sizes of their phone in the correct order (small farthest) but consistently set its size larger than expected (p < .001). When setting its size at the distance they had previously chosen as consistent with a given size, they surprisingly set it significantly larger (p < .001). In exp2, where they set size first, the distances set in task 2 were not significantly different from task 1 (p = .936). Participants could not use distance given in meters. Our results suggest that people misjudge the visual size of a familiar object based on its perceived distance, setting it much too big. When determining object distance based on visual size, however, they are quite consistent. The perceptual relationship between size and distance seems to break down when an object of known physical size is placed in a 2D scene.

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Discrete field-of-view primes reinstate holistic representations of 360° space

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We experience our visual environment in discrete glances. How do we build a unified representation of a 360º visual environment? One possibility is that neighboring scene views become associated through concurrent activation during learning, enabling a single view to subsequently prompt reactivation of the surrounding environment. In this study, we used Virtual Reality (VR) to ask whether a single view in an immersive panorama primes perceptual judgements of adjacent views in 360º space. In the Study Phase, participants (N=6) learned 18 real-world panoramas using head-mounted VR. In the Priming Test, on each trial, participants made a perceptual (open/closed) judgement on a target image taken from a studied panorama (110º field-of-view). Participants turned their head to view the target, which appeared either on their left/right in 360º space. Before target onset, a brief (300ms) prime image was presented directly ahead, either depicting: 1) an adjacent snapshot from the same panorama as the target (Valid prime), 2) a snapshot from a different panorama (Invalid prime), or 3) a grey box (Neutral prime). In an Explicit memory test, on each trial, participants reported whether a snapshot had appeared on the left/right/front in the panorama during learning. We found a significant effect of priming condition on reaction time ($p<.01$): participants were faster to make open/closed judgements when primed with an image from the same panorama (Valid prime condition) as compared to the Invalid ($p<.01$) and Neutral prime conditions ($p=0.1$). Explicit memory performance was high (>85%) for all participants, indicating accurate learning of the panoramas. We show that discrete views of a panorama prime each other in 360º space. These results suggest that spontaneous reinstatement of unseen, adjacent views may play an important role in facilitating ongoing perception and maintaining a seamless sense of our 360º visual environment.

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Systematic transition from boundary extension to contraction along an object-scene continuum

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After viewing a picture of a scene, our memory of it typically extends beyond what was presented—a phenomenon called boundary extension (Intraub et al, 1992). However, recent work has found evidence for boundary contraction as well (Bainbridge & Baker, 2020), proposing different outcomes for object-focused and scene-focused images. In naturalistic visual experience, there is a continuum of views that naturally transition between scene-focused and object-focused, e.g., as an observer enters an indoor environment and moves toward an object. Here, we examined how memory for a view of an environment changes along this object-scene continuum. We constructed 3D indoor environments using a virtual-reality game engine, allowing for tight control of their spatial dimensions and object content, and captured a series of images at systematic distances from a center object within each environment. We found continuous progression from boundary-extension in close-up views to boundary-contraction in distant views, with a consistent transition point across environments, and a clear relationship between the magnitude of the memory distortion and the position along the continuum. In a series of subsequent experiments, by manipulating the number of objects in the environment, we found that the memory transition point is not linked to a specific depicted distance per se, e.g., the transition between reachable and non-reachable space. Rather, the position at which boundary extension transitions to boundary contraction seems to track with the views that “looked best,” as judged by independent observers. Taken together, these results demonstrate that there is indeed a systematic link between the direction of memory distortion and the depicted scale of the space, but where object content has a clear influencing role. Further, the

correspondence between the best view and the transition point suggests a common underlying mechanism, providing new empirical inroads for articulating the mechanisms of visual scene encoding.

Acknowledgements: R21EY031867

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The adult visual system resists learning continuity violations

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One universal property of our world is that solid objects behave under the principle of continuity: they cannot spontaneously appear or disappear. Consequently, human vision may be equipped with strong prior expectations for this basic principle (Falck et al, 2020; Flombaum & Scholl, 2006). Here, we tested people's resistance to learning continuity violations after being trained to expect such violations. In Experiment 1, participants performed an object detection task. Each trial first showed a car or an empty space, which was then occluded by an opaque screen. Next, the screen fell, revealing a car or an empty space, and participants responded within 500ms whether the car was present or absent. They first went through a training phase of eight violation trials (i.e., car present at first, absent at reveal, or vice versa) or eight non-violation trials. They were then tested on a violation or non-violation trial. Results showed that after being trained on violations, participants' accuracy was surprisingly near 100% both when tested on violations and non-violations. Whereas following non-violation training, their accuracy was near 100% for non-violations, 56.0% for violations. This suggests that participants could learn to expect violations through training, but could not learn to override the expectation of a non-violation. Experiment 2 asked participants to predict the car's presence or absence and give a confidence rating before seeing outcomes in training and test trials (while no longer employing the detection task). Here, following violation training, only 70.6% participants predicted a violation, with an average confidence of 5.41/7, while following non-violation training all participants predicted non-violations (avg. confidence of 6.60/7). Taken together, our studies provide evidence for a strong prior in human vision for expecting continuity and a generic influence of this prior in learning to expect statistically improbable non-violations (Experiment 1) and statistically probable violations (Experiment 2).

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Influences on the visual categorization of naturalistic structures in infancy and early childhood

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Detecting and categorizing particular entities in the environment are important visual tasks that humans have had to solve over evolutionary time. Here we investigate whether characteristics of ecologically-significant entities play a particular role during the development of visual categorization. To do this, the current project examined the effects of developing visual abilities, visual properties and ecological significance on categorization. Our stimuli were monochromatic photographs of structure-like assemblies and surfaces taken from three categories: vegetation, non-living natural elements, and artifacts. A set of computational and rated visual properties were assessed for these stimuli. We conducted two empirical studies: (a) two card sorting tasks with 76 preschool children (age: 4.1-6.1 years) and 72 adults (age: 18-50 years) which assessed classification and similarity judgments, and (b) a gaze-contingent eye-tracking search task with 39 infants (8-month-olds) in which target-structure patches were placed on a discrepant background structure, and the impact of properties and categories on infants' search performance was investigated. We found that category membership and visual properties impacted the performance of all participant groups. Sensitivity to the respective categories varied between tasks and over the age groups. For example, artifact images hindered infants'

visual search but were classified best by adults, whereas sensitivity to vegetation was equally high for all age groups during visual search or similarity sorting. In children and infants, rated depth predicted task performance stronger than shape-related properties. Moreover, children and infants were sensitive to variations in the complexity of low-level visual statistics. These results suggest that classification of visual structures, and attention to particular visual properties is affected by the functional or ecological significance these categories and properties may have for each of the respective age groups. Based on this, the project highlights the importance of further developmental research on visual categorization with naturalistic, structure-like stimuli.

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Neurophysiologically-inspired model for social interactions recognition from abstract and naturalistic stimuli

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INTRODUCTION: Humans can perceive social interactions from natural as well as from schematic stimuli, as shown by the classical experiments by Heider and Simmel (1944). We present a simple neural model that is consistent with the basic facts known about neurons in the visual pathway that recognizes social interaction from naturalistic as well as from abstract stimuli. In addition, we present an algorithm for the generation of highly-controlled stimulus classes of naturalistic and abstract social interactions. Such stimuli are critical for electrophysiological and psychophysics experiments that clarify the underlying mechanisms. METHODS: The model consists of a hierarchical shape-recognition pathway with partial position invariance that is modeled using a deep neural network (VGG16), followed by an estimation of the relative instantaneous positions and orientations of moving agents, which are then robustly tracked and encoded by a population code in a Dynamic Neural Field. The relative positions, velocities and accelerations of moving agents are computed in a top level module, employing gain-field mechanism which is followed by the classifier of the interactive behaviors. The stimulus synthesis algorithm is derived from dynamic models of human navigation (Warren, 2006) which are combined with methods for computer animation of quadrupedal animals. RESULTS: The model successfully reproduces results of Tremoulet and Feldman (2000) on the dependence of perceived animacy of moving agents on their motion parameters and the body axis. We demonstrate how the proposed architecture can recognize interactions from real movies showing interacting animals. The most distinctive three behavioral classes scored better than 71% in terms of the true positive rate. The model makes predictions about the behavior of a variety of different neuron classes, which guide the analysis in physiological experiments. CONCLUSION: Simple neural circuits combined with learning are sufficient to account for simple forms of social interaction perception in real and abstracted stimuli.

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Comparison of threshold measurements in laboratory and online studies using a Quest+ algorithm

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Online experiments have become popular and it is useful to test how data collected online compare to data measured in the laboratory. Here we compared perceptual thresholds of the perceived quality of computer-generated images (CGI) in a large-sample (N=174) measured online, and a smaller-sample (N=71) obtained in a laboratory-controlled study. Stimuli were three sets of CGIs picturing different scenes of the interior of an apartment. The algorithm used for generating the images reduces the amount of visual noise when the computation time increases so that each successive image within a set has less noise than the previous one. The last generated image of each set (i.e. with the less visual noise) was used as a reference image (RI) and compared to other images of the set. Each comparison image (CI), was cut randomly and the missing part was replaced by its corresponding part from the RI. On each trial observers had unlimited time to report whether they see a single or a composite image. We used a QUEST+ Bayesian adaptive method, which minimizes the expected Shannon entropy, to choose the next CI after each trial. Perceptual thresholds were expressed relatively to the size of the image set. Although online participants reached a stable threshold in fewer trials than laboratory participants (90 vs 156 trials on average, respectively), the equivalence test (TOST) revealed a significant similarity ($p<0.05$) between the online and laboratory perceptual thresholds. Online measurements also replicated the effects of the scene (THRESHOLDscene1=0.38, MADscene1=0.12; THRESHOLDscene2=0.35, MADscene2=0.09; THRESHOLDscene3=0.42, MADscene3 =0.08) we observed in the laboratory (THRESHOLDscene1 = 0.39, MADscene1 =0.11; THRESHOLDscene2 = 0.38, MADscene2 =0.09; THRESHOLDscene3 = 0.41, MADscene3 = 0.11). Overall, this study shows consistent data collected online and in the laboratory. Despite strong differences in experimental conditions, online measurement of perceived image quality could accurately substitute the laboratory measurements.

Acknowledgements: Funding from ANR grant ANR-17-CE38-0009

Perception and Action: Neural mechanisms 2

Poster Session I > Perception and Action: Neural mechanisms 2 > Poster I92

Visual to motor cross-decoding of hand shapes from mirror neuron activity

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We recently demonstrated that the dorsal premotor cortex (PMd) of macaque monkeys houses mirror neurons (MirNs). MirNs, originally described in the ventral premotor cortex, are sensorimotor neurons that fire both when an animal performs an action and when the same animal observes another agent performing an identical or similar action. Here, we investigate whether a decoder trained on the activity induced during action-observation can reliably distinguish hand grips using the activity induced during action-execution. To this end, we use neuronal spiking cortical activity recorded from the PMd of macaques engaged in execution and observation of reaching-to-grasp actions. Decoding of actions is done by a Support Vector Machine with a linear kernel function using the activity occurred in 200 ms periods (starting 800 ms before and ending 1400 ms after movement onset) at various temporal combinations between observation and execution. Classification performance, using either the whole set of units (n=140) or subsets of units of various sizes, was at 50% regardless of the number of included units. To overcome this issue, a greedy-approach was employed: the unit with the best performance was initially selected and at each subsequent step a unit was added to those of the previous step so that to maximize the performance of the resulting population. Following this approach we reached cross-decoding accuracy above 90% using less than half of the population. Thus, a selected subset of units, that shares the same computations in the execution and observation, is sufficient for effective and consistent inter-condition decoding of grips. These results demonstrate that PMd-MirNs can provide a reliable signal for the development of grip decoders which could be trained even when the required registration of neural activity and behavior can’t be obtained due to the incapability of generating overt movements.

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Poster Session I > Perception and Action: Neural mechanisms 2 > Poster I93

How visual feedback influence neural dynamics in macaque medial posterior parietal cortex

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Understanding the neural computations involved in different motor behaviours is extremely challenging, and it is even more complicated to study the effect of visual background on movement-related neuronal activity in associative parietal areas. Single neuron approaches could only provide a limited view on how neural computations are carried out, without considering network connectivity and timing relationships between single neuron discharges. Networks of interconnected neurons could in principle generate a huge number of activity patterns, but Hebbian theory, anatomical connectivity, and plasticity constrain the neural population to discharge according to a rather small number of “neural states”. Here, we recorded 44 neurons from V6A, a visuomotor area of the medial posterior parietal cortex, in a Macaca fascicularis monkey while the animal performed a delayed reaching task towards 3 targets placed at different directions. Reaching movements occurred in the light and in the dark. To study the ‘neural states’, we applied an unsupervised machine learning method, the Hidden Markov Model. We also applied a neural dimensionality reduction technique to highlight differences in neural patterns. We found that both conditions (light and dark) produce similar sequence of neural states whose timing coincided with observable task events. Generalization analysis revealed that, even if the produced behavior and the neural states are apparently the same, the two contexts elicit different population activity patterns. This is also confirmed by the neural trajectories that, depending on the visual background, seem to be confined in two different subspaces with a proper temporal and spatial evolution. These results support the key role of the medial posterior parietal cortex in computing visuospatial transformations during static and dynamic phases of a reaching movement. This aspect needs to be investigated in future studies to understand how the different visual background and the vision of the hand modulates this area.

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Poster Session I > Perception and Action: Neural mechanisms 2 > Poster I94

Differential visuomotor and somatosensory claustral inputs to macaque medial posterior parietal cortex

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The macaque medial posterior parietal cortex (mPPC) is involved in the analysis of sensory signals for the control of movement. Here, we describe the claustral input to the mesial and lateral part of mPPC, specifically areas PGm and MIP, and compare them with those of adjacent areas. Four injections of retrograde neuronal tracers were restricted to PGm and MIP and one injection each to areas V6Ad, 31, PEci, PEip, and LIP, in 10 hemispheres of 10 animals (7 Macaca fascicularis, 2 M. nemestrina, 1 M. mulatta). Injections were placed by direct visualization of regions of interest, and the location of injection sites was reconstructed post mortem on cyto- and myeloarchitectural bases. All examined parietal areas received monosynaptic afferents from the claustrum, predominantly from its posterior half. Injections in PGm, as well as in LIP, revealed a continuous stripe of labelled cells along the rostrocaudal extent of the claustrum: 50% of labelling occupied the postero-ventral part of the claustrum, while the remaining 50% was distributed in the antero-ventral (30%) and antero-dorsal (20%) part. Claustral projections to MIP were less homogeneous: posterior injections showed a similar pattern to PGm, even if anteriorly limited to the dorsal quadrant; rostral injections, likewise in V6Ad, showed projections in the posterior half of the claustrum, mainly within the postero-ventral quadrant. Claustral afferents to areas PEci and PEip were concentrated in the postero-dorsal quadrant, while afferents to area 31 were mainly in the postero-ventral quadrant, in a middle position between PGm and PEci afferents. The origin of claustral projections to posterior parietal areas reveals a functional topography within this structure: the postero-ventral and anterior claustrum are respectively related to visual and motor cognition (see projections to PGm and MIP), whereas the dorsal part of the claustrum is likely involved in somatic processing (projections to PEci and PEip).

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Poster Session I > Perception and Action: Neural mechanisms 2 > Poster I95

Neural correlates of eye-position and proprioception during reaching in the superior parietal lobule of the macaque

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Reaching and manipulative actions allow human and non-human primates to interact with the surrounding world. The execution of foveated reaching movements requires the combination of visual and motor skills, allowing the arm to be guided and kept in place by several kinds of information (eye position, proprioceptive, visual). Several areas of the superior parietal lobule (SPL) are involved in the progressive integration of information related to the current position of the eyes and proprioceptive signals from the arm occurring during and after reaching movements. In this study we assessed the relative influence of eye-position and somatosensory signals during static arm positions at the end of a 3D fixation-to-reach task in three SPL areas: V6A, located in the anterior bank of the parieto-occipital sulcus, PEc, bordering anteriorly to V6A, and PE, located more rostrally in the SPL. We analyzed single cell discharges recorded from areas V6A (N= 303), PEc (N= 264) and PE (N= 189) of two Macaca fascicularis in two main time intervals: i) target fixation and ii) holding of the foveated target. We found that the three areas were differently modulated by eye-position and proprioceptive signals, being PE cells more involved in the encoding of limb postures while V6A and PEc neurons more involved in the processing of eye-position information during target fixation. Our results support the existence of a functional antero-posterior trend along the SPL: from area PE, strongly dominated by proprioceptive signals of the arm holding the target, to the most functionally heterogenous areas PEc and V6A, which showed an additional gaze influence. This coding scheme parallels the increase of somatosensory and the simultaneous decrease of visual processing observed along the caudo-rostral axis of the SPL.

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Spatial Vision: Psychophysics 2

Poster Session I > Spatial Vision: Psychophysics 2 > Poster I96

Contrast sensitivity is formed by visual experience and task demands

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The contrast sensitivity function (CSF) is a fundamental signature of the visual system and has been measured extensively in numerous species. It is defined by measurements of the visibility threshold for sinusoidal gratings at all spatial frequencies. Here, we measured the CSF in artificial visual systems, namely deep neural networks (DNNs), using the same contrast discrimination paradigm as used in human psychophysical experiments. During training, networks are exclusively exposed to natural images, and the task is to identify which one of two input images has higher contrast. The contrast discriminator networks learn a linear classifier over frozen features of pretrained DNNs. At the testing stage, we measured the network's CSF by presenting sinusoidal gratings of different orientations and spatial frequencies. Our results demonstrate that the pretrained DNNs show the band-limited, inverted U-shaped CSF, that is characteristic of the human CSF. The exact shape of the DNNs' CSF appears to be task-dependent. The human CSF is better captured by scene segmentation DNNs than image classification ones (tested under identical settings such as the architecture and computational complexity). When the network was trained to discriminate the contrast in natural images from scratch (i.e., with no previous training task), a relatively flat CSF emerged, dissimilar to the human CSF. The environment of pretrained DNNs proved influential as well. Those with a diet of natural images, similar to human experience (e.g. objects or faces), obtain more human-like CSF. Pretrained DNNs with aerial pictures, such as a bird flying in the sky would see, obtain a shifted CSF towards higher spatial frequencies, similar to that of an eagle. In conclusion, the CSFs

derived from the DNNs are the result of efficient processing of the natural world around us. Different visual environments have succinct effects on the shape of the CSFs.

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Effect of age on threshold and suprathreshold contrast vision

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The purpose of our study was to investigate the difference in spatio-chromatic contrast vision between younger (below 40) and older (above 60) colour-normal observers. We were particularly interested in how the adapting light level affected contrast vision and whether there was a differential age-related change in contrast threshold as well as suprathreshold contrast matching. There are two parts of the study, (i) contrast threshold measurement, (ii) suprathreshold contrast matching. In threshold measurement task, contrast sensitivity was measured for Gabor patches of 5 spatial frequencies (0.5, 1, 2, 4, and 6 cpd) in achromatic and two chromatic directions, at background luminance levels ranging from 0.02 to 10,000 cd/m^2. In the contrast matching task, a reference stimulus was displayed at a fixed luminance level and observers adjusted the contrast of the test stimulus displayed at different luminance levels (0.02 to 2000 cd/m^2). The matching experiment was repeated for 0.5, 2, and 4 cpd for all three colour directions at three suprathreshold levels of increasing contrast. Our main findings are: (1) Contrast sensitivity increases with background luminance up to around 200 cd/m2, then either declines in case of luminance contrast sensitivity, or becomes constant in case of chromatic contrast sensitivity; (2) The sensitivity of the younger age group is higher by ~0.3 log units; (3) Contrast sensitivity at higher spatial frequencies is more affected by ageing; (4) The differences between old and young group are not carried over to suprathreshold levels. Our results show that the effect of age on suprathreshold contrast matching is small in comparison to the age-related decline in contrast sensitivity (Mei et al, 2007) which is consistent with the hypothesis that contrast sensitivity at threshold is limited by different factors than suprathreshold vision.

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Spatial properties of the adaptation-based compression of perceived distance

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To perceive geometric properties of external objects, the visual system must map their physical relations onto intrinsic, non-isomorphic neural representations. This mapping can be modified by adaptation: exposure to a texture reduces the perceived separation between objects (Hisakata, Nishida, & Johnston, 2016). Here we investigated the spatial reach of this effect. After presentation of an adaptor (a dynamic irregular grid of black and white dots), in either the left or right visual field, two pairs of dots appeared on either side of the fixation: a standard (1 dva separation) and a test pair (variable separation). Participants reported which pair appeared to have a greater inter-dot separation. To test the spatial tuning of the effect, the position of the standard relative to the adaptor varied. When presented in the adapted region, the standard appeared compressed by ~30%. The compression decreased (~10%) when the dots straddled the adaptor's edge, and disappeared when the standard and adaptor were not-overlapping, suggesting a narrow tuning of the compression effect. To test whether the compression occurs in retinotopic or world-centered coordinates, participants shifted their gaze after the adaptation to an intermediate, and then to a final, test location. This allowed us to present the standard at either the same retinal or screen coordinates as the adaptor. Performance was compared to conditions where gaze remained fixed across adaptation and test periods, and the standard was presented either at adapted (full adaptation) or non-adapted (control) locations. We found evidence for both retinotopic and world-centered transfer of the distance compression, albeit with reduced magnitude (~50% and 70% relative to the full adaptation condition, respectively). The results suggest that mechanisms transforming external geometrical properties to neural representations can at least partly compensate for differences between retinal images and object positions in the external world induced by eye movements.

Acknowledgements: This work is supported by the Leverhulme Trust

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Y-like human psychophysical responses to contrast modulated patterns

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Cat Y-type retinal ganglion cells (RGCs) and macaque parasol cells are distinguished by responding nonlinearly to high spatial frequencies (SFs) and temporal frequencies (TFs). However, the contribution of these RGCs to human visual perception are not well understood. Here we devised a psychophysical approach to reveal the function of human Y-like RGCs. We take advantage of the Y-like carrier response properties of cortical neurons to contrast modulated (CM) patterns which consist of a high SF contrast-reversing grating carrier whose contrast is modulated by a low SF drifting sinewave envelope (0.25 cpd, 3 Hz). In each stimulus trial, subjects reported the direction of motion of CM envelopes or luminance modulated (LM) gratings at 2.1, 4.3, 6.4, or 8.5 degrees of eccentricity. Within each block of trials, SF (for LMs) or carrier SF (for CMs) was varied with the method of constant stimuli for different values of TF (LMs) or carrier TF (CMs). We found that the best performance for LM patterns was at lower TFs (5-10 Hz) and at lower SFs, which decreased systematically with eccentricity. However, CM pattern performance was bandpass with carrier SF, displaying the best performance at 1.5-3.0 cpd, and high carrier TFs (15-20 Hz). At the highest carrier TF (20 Hz), performance did not decrease systematically with eccentricity. The nonlinear subunits of Y-type cells respond better at higher TFs than linear mechanisms respond to gratings. Therefore, the measured psychophysical performance for CM patterns is consistent with nonlinear subunits. Furthermore, the good performance at SFs that are high for peripheral vision and rather independent of eccentricity is more consistent with the responses of small nonlinear subunits than with linear mechanisms.

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Poster Session I > Spatial Vision: Psychophysics 2 > Poster I100

Spatial modulation of contour integration: The role of eccentricity, inter-element spacing and display density

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The ability to detect a contour among randomly aligned elements has been studied extensively and led to the proposal of the association field: a spatial window in which elements can be linked into contours. Human vision is presumed to depend on two other distinct visual fields: receptive fields which constrain the low-level processing of contrast, and integration fields which determine the spatial windows in which elements can be integrated into a common texture and lose their individual features. Theories of mid-level vision would benefit from having a common framework that encompasses neural processing across these different fields. However, it is notoriously hard to study whether association fields are modulated by spatial properties similarly to perceptive fields and integration fields. The difficultly does not only stem from the longer extent over which elements can be combined, but also from the confoundability between effects of element eccentricity, inter-element spacing, and display density. In the current study, these factors were manipulated in a way that allows assessment of their respective influence on contour integration. Participants were presented with a spatial 2AFC "snake in the grass" task with three eccentricities (7°, 10.5° and 15.75°), five inter-element spacings (0.7°,1.05°,1.58°,2.36° and 3.54°), and three orientation "wiggles" (5°, 15° and 25°). "Snakes" consisted of seven elements which were equally distant from fixation. We found that at moderate eccentricities (7° and 10.5°), contour integration was successful over the full range of inter-element spacings. Yet, at a farther eccentricity (15.75°) elements needed to be closer, especially for the strongest "wiggle". This implies that unlike integration field sizes, association field sizes do not scale with eccentricity, with smaller association fields in the periphery.

Acknowledgements: This project was supported by a BBSRC project grant (BB/R009287/1)

Spatial Vision: Neural Mechanisms 2

Contrast surround suppression in people with psychosis: A behavioral and 7 tesla fMRI study

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People with psychosis experience abnormal visual percepts (e.g., hallucinations). It is unknown if these differences are unique to specific diagnoses, or are influenced by genetic liability for psychosis (as in close biological relatives). The underlying neural processes also remain largely uncharacterized. Based on previous studies, we hypothesized people with psychosis would show reduced surround suppression during visual contrast perception, versus controls. The current study, part of the ongoing Psychosis Human Connectome Project, examined contrast surround suppression using behavioral and 7 tesla fMRI data from 43 people with psychosis (schizophrenia, schizoaffective, or bipolar diagnoses), 34 unaffected first-degree biological relatives, and 26 healthy controls. In our behavioral experiments, contrast discrimination thresholds were determined using circular gratings at seven contrast levels (0-20%). We previously showed higher contrast discrimination thresholds (without surrounds) for people with psychosis in this task. Here, we quantified threshold elevation for 10% contrast targets with a surrounding annulus (100% contrast) versus without. We expected to see less threshold elevation with surrounding stimuli in people with psychosis, compared to controls or relatives. However, no such difference was observed. 7T fMRI responses were measured in the lateral geniculate nucleus, primary visual cortex (V1), and lateral occipital complex (LOC) during a similar task at four contrast levels (10-80%). Contrast-dependent responses in V1 and LOC were suppressed by the presence of the surrounding stimulus. While there were no group differences in V1 fMRI responses, LOC responses showed greater surround suppression in controls than in relatives or people with psychosis, consistent with previous behavioral findings. While our behavioral results do not suggest weaker surround suppression in people with psychosis, there was mixed evidence for such a difference from fMRI responses in visual cortex.

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Cross-dataset reproducibility of population receptive field (pRF) estimates and retinotopic map structure

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Intro: PRF models fit to fMRI data are a component of many visual experiments. It is important to know how reliable pRF parameters are across experimental conditions. We compared retinotopic maps and pRF properties across two datasets obtained with different fMRI protocols and stimulus designs: a newly acquired dataset from New York University (NYU) (n=44) and a public dataset from the Human Connectome Project (HCP) (n=181). The datasets differ in many ways, including field strength (3T vs 7T) and voxel size (1.6 vs 2 mm). Method: PRF parameters (polar angle, eccentricity, and pRF size) were estimated using vistasoft software (https://github.com/vistalab/vistasoft) on group-averaged time-series (registered to the fsaverage surface) and on each individual subject's time-series. Result: Within V1, V2, V3, and hV4, the vertex-wise polar angle estimates of the group-averaged data were similar between the two datasets (r=0.97, V1-hV4). The eccentricity estimates were also highly correlated (r=0.94) but with a small bias toward higher eccentricities in the NYU dataset. On average, pRF size estimates were correlated (r=0.81) and showed a greater systematic difference between datasets: They were larger (by 0.5 to 1º) in the NYU dataset across comparable eccentricities (0.5-6°) and visual areas. Finally, we examined a large-scale property of the maps in individual subjects, polar angle asymmetries in V1 cortical magnification. These were recently described in the HCP dataset (Benson et al., 2020): Here we show that the NYU dataset replicates the finding that more V1 cortical surface area represents the horizontal than vertical visual

field meridian, and the lower than upper vertical meridian. Conclusion: The retinotopic maps (polar angle, eccentricity, cortical magnification) are consistent between the datasets, indicating a high degree of reproducibility despite numerous experimental differences. PRF sizes are roughly 1º larger in the NYU dataset, a difference that may be due to larger voxel sizes.

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Poster Session I > Spatial Vision: Neural Mechanisms 2 > Poster I103

Can neurochemical concentrations in the visual cortex differentiate patients with psychosis from healthy controls via multivariate decoding?

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Many prominent theories of visual anomalies (e.g., hallucinations) in schizophrenia suggest differences in neurotransmitter levels in the visual cortex. For example, imbalances in excitatory and inhibitory neurotransmitters (e.g., glutamate and GABA) may contribute to psychotic symptoms. Previous studies using proton magnetic resonance spectroscopy (MRS) have reported differences in concentrations of GABA, glutamate, glutamine, N-acetyl aspartate (NAA), and glutathione (GSH) among patients with schizophrenia. It is not yet clear whether neurochemical differences are specific to schizophrenia, or may be present among patients with psychotic disorders more broadly. The role of genetic risk for psychosis in neurochemical dysfunction is also not clear. We sought to determine whether and how patterns of neurochemical concentrations in the visual cortex might differ in people with psychosis and their first-degree biological relatives. As part of the ongoing Psychosis Human Connectome Project, we acquired 7 T MRS (STEAM) data in the visual cortex, scaled to water, from 45 patients with a psychotic disorder (schizophrenia, schizoaffective disorder, or bipolar disorder), 29 non-psychotic biological relatives, and 36 healthy controls. We found no significant univariate differences in GABA or glutamate levels between groups. There were trends towards group differences for several other metabolites, including NAA and macromolecules, but these did not survive correction for multiple comparisons. Using 5-fold cross-validated multivariate decoding (support vector machine) analyses, we sought to differentiate between patients, relatives, and controls based on the pattern of metabolite concentrations in the visual cortex from MRS. Preliminary results from our decoding analysis suggest that the neurochemical profile from MRS may reflect neural dysfunction in early visual cortex among patients with psychosis, and may be associated with genetic risk for psychosis.

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Poster Session I > Spatial Vision: Neural Mechanisms 2 > Poster I104

Information redundancy across spatial scales modulates early visual cortex responses

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Visual images contain redundant information across spatial scales. Previous research suggests that the visual system makes use of those redundancies to facilitate efficient processing. In this framework, a fast initial analysis of low-spatial frequency (LSF) information informs the slower and later processing of high spatial frequencies (HSF). We hypothesized that LSF-guided processing is implemented through LSF-informed feedback from higher-order regions to facilitate the integration of HSF information in early visual cortex. To test our hypothesis, we analyzed magnetoencephalography responses to the passive viewing of images of either intact faces or their phase-scrambled version filtered to contain LSF, HSF or LSF + HSF information (broadband). Importantly, only in the intact broadband condition are LSF and HSF correlated (i.e. containing redundant information). We observed a reduction in the markers of HSF processing for the

intact compared to the scrambled condition using a cross-classification approach. This reduction was accompanied by a decrease of power in the gamma frequency band response in a region of interest centered on the calcarine sulcus. However, contrary to our hypothesis we found no evidence for a correlation with response power or phase in the feedback associated beta frequency range response in either fusiform gyrus or frontal cortex. Instead, Bayesian analysis favored the null hypothesis that higher level beta band activity is statistically independent from early visual cortex gamma power. Our findings call into question whether higher-level feedback to early visual cortex is necessary for cross-spatial frequency redundancy to be beneficial to visual perception. Instead we propose that early visual cortex itself can take advantage of the statistical regularities of natural images for the economical processing of redundant information.

Structure-function relationship of retinal ganglion cells in multiple sclerosis

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Objective: To investigate functional and structural retinal changes in multiple sclerosis patients (MS) with history of optic neuritis (HON) and without (NHON). Methods: In this cross-sectional study, 12 NHON, 11 HON and 14 control participants were included for multifocal pattern electroretinography (mfPERG) and optical coherence tomography (OCT) measurements. MfPERG was recorded (Veris Science) with a circular dartboard pattern (22° radius) comprising 36 elements. Amplitude and latencies of the mfPERG components N35, P50 and N95 were assessed. Macular OCT scans were acquired to determine ganglion cell layer (GCL) and inner plexiform layer thickness (IPL) and optic disc OCT scans were acquired to assess the total (G), papillomacular bundle (PMB), and temporal (T) peripapillary retinal nerve fiber layer thickness (pRNFL). Group differences and crossmodal associations were assessed. Results: For mfPERG, only the central ring's N95 amplitude [$F(2,34)=7.8$, $p=0.008$] was altered, i.e. a reduction in HON and NHON vs. controls [mean (±SE) difference: -0.5 ± 0.13 µV ($p=0.002$) and NHON -0.3 ± 0.13 µV ($p=0.048$), respectively]. For OCT, parafoveal GCL [$F(2,34)=13.8$, $p\leq0.001$] and IPL thicknesses [$F(2,34)=8.1$, $p=0.003$] were lower in HON vs. controls [mean difference: 11.6 ± 2.2 µm ($p\leq0.001$) and 5.7 ± 1.4 µm ($p\leq0.001$), respectively]. Perifoveal GCL thickness [$F(2,34)=6.5$, $p=0.008$] was also significantly reduced in HON vs. controls. The T [$F(2,32)=5.2$, $p=0.022$] and PMB [$F(2,32)=6.5$, $p=0.012$] pRNFL sectors showed reductions in HON vs. controls [mean difference: 16.2 ± 5.1 µm ($p=0.01$) and 13.5 ±3.9 µm ($p=0.004$), respectively]. Crossmodal correlations were observed only for the central N95 amplitude and perifoveal GCL thickness (r:-0.47, $p=0.036$). Conclusion: Central N95 amplitudes were reduced in MS, both in HON and NHON groups. As the N95 is associated with the ganglion cell axons[1], these finding might indicate early foveal axonal dysfunction not only in HON, but also in NHON patients. [1]Bach et al Exp Eye Res. https://doi.org/10.1016/j.exer.2018.01.021

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Comparison of decoding of visual-evoked potentials from tri-polar and conventional EEG

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Tri-polar concentric ring electrodes (tCREs) offer a promising avenue for collecting visually-evoked potentials (VEPs) while minimizing certain artifacts that are common to traditional electroencephalography (EEG). We previously showed that VEPs recorded using tripolar EEG (tEEG) were generally comparable to those collected (simultaneously) from an emulated standard EEG signal (eEEG), with some subtle differences in the latency of the N70 and P100 components. Here, we used multivariate decoding analysis to compare the nature of the information carried by each electrode type.

We recorded VEPs to large (1°) or small (0.25°) contrast-reversal checkerboard patterns at 7 different retinal locations. A linear discriminant analysis (LDA) classifier was trained and tested at every ms time point (0-496 ms post-reversal), separately for tEEG and eEEG signals. Results from the decoding of large vs. small checkerboards, left vs. right hemifield, and four quadrant locations were qualitatively similar. The time course of decoding was similar across the two types of electrodes, with significant above-chance decoding observed between ~75-350 ms. Decoding of the eEEG signal tended to produce slightly earlier and higher peak classification compared to the tEEG signal. As expected, decreasing the number of trials included led to worse decoding performance; peak decoding performance was achieved with ~40 trials per condition for both types of data. Consistent with the observed VEPs, the time course of decoding from the tEEG electrodes appeared shifted later in time by ~25 ms. For some comparisons, decoding based on signals from both tEEG and eEEG channels produced significantly better decoding than tEEG or eEEG alone, suggesting that the tEEG and eEEG signals may be sensitive to slightly different but overlapping neural sources. These results further demonstrate the utility of tEEG collected from tCREs to quantify the informational content of visually-evoked potentials.

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Visual Memory: Capacity and content

Poster Session I > Visual Memory: Capacity and content > Poster I121

Fragile Memories for Fleeting Percepts

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Our perceptual systems are exceptionally good at searching our sensory environments for salient stimuli. A key question is the extent to which this search is performed subliminally. We explore this using Rapid Serial Visual Presentation (RSVP), by comparing detection performance with the memory left for distractors, the stimuli that have to be rejected as non-targets in the process of searching for targets. To assess the impact that conscious perception has on the fragility of memories, we explore three Stimulus Onset Asynchronies (SOAs): 117ms, 230ms, and 350ms. 26 participants were instructed to search for a target word in each RSVP stream. At the end of the trial, they indicated the presence/absence of the target. In half of the trials, they responded to a free-recall or a recognition memory question. We calculated accuracy (for Free-recall) and d-prime (for Recognition) for each of the last 3 distractors presented in the stream in order to contrast the recency effect (a key marker of the fragility of memory representations) between the two memory tasks. Recall performance at 117ms was extremely low: the -1 item was correctly recalled on approximately one in five streams and, on average, a -1 to -3 item was recalled correctly on less than one in ten streams. Recognition performance was higher and less subject to recency, but still substantially lower than Detection performance. Comparing the recency effect across the three SOAs, it seems that there is a large change in free recall performance from 117ms SOA to 230ms SOA that is not present for recognition. We argue that these findings suggest that the brain subliminally searches for salient stimuli, and are also consistent with a theory we call the tokenized-percept hypothesis, which links conscious perception to the process of episodically marking experiences.

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Induced forgetting is the result of true forgetting, not shifts in decision-making thresholds

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Induced forgetting occurs when accessing an item in memory appears to harm memory representations of categorically related items. However, it is possible that the actual memory representations are unharmed. Instead, people may just change how they make decisions. Specifically, signal detection theory suggests this apparent forgetting may be due to subjects shifting their decision criterion. Here we used behavioral and electrophysiological measures to determine whether induced forgetting is truly due to changes in how items are represented or simply due to a shifting criterion. Subjects' behavior and brain activity showed that induced forgetting was due to changes in the strength of the underlying

representations, ruling out the simple signal detection theory explanation of induced forgetting.

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Is attribute amnesia really just forgetting?: Assessing the influence of reading on surprise trial performance

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Attribute amnesia (AA) reflects a failure to report a target-defining feature for a stimulus that had just been attended. For example, if participants are asked to report the location (i.e. the response attribute) of a letter among digits, they are unable to report the identity of that letter (i.e. key attribute) in a surprise trial. A summation of AA findings has led to the hypothesis that AA represents a lack of encoding of the key attribute. However, given the nature of the surprise paradigm used to assess AA (surprising event, response remapping, delayed responding, etc.), it is possible that decreased accuracy could be largely attributable to forgetting effects or interference caused by reading the surprise question. This study assessed the extent to which interference induced by unexpected reading contributes to decreased surprise trial accuracy. Participants completed a modified surprise trial paradigm: instead of being surprised with a new question, they were presented a task-unrelated passage to read before answering the same question as before surprise. In one condition a remember cue was presented before the reading passage. Without the cue, participants had poor accuracy following the reading passage, but with the cue performance increased dramatically. This remember cue was then applied to a standard surprise trial paradigm in which the question itself was unexpected. Though cueing to remember slightly improved surprise trial accuracy, it did not remove the AA effect. These results demonstrate that intentionally encoded information in working memory is more resilient to interference than briefly attended attributes that are not expected to be required for report. Thus, though some forgetting contributes to poor accuracy on the surprise trial in AA paradigms, our results support the hypothesis that AA is induced by a lack of encoding of the key attribute.

Acknowledgements: This work was funded by NSF Grant 1734220

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Isolating Working Memory Capacity Deficits from Sustained Attention Deficits in Patients with Schizophrenia Using a Single Behavioral Task

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Recent advances in our understanding of working memory (WM) suggest that performance on tasks that assess WM confound an individual's maximum WM capacity with trial-to-trial variations in their attentional control. This limitation regarding one of the most commonly assessed cognitive constructs in clinical psychology raises important questions regarding the true locus of performance deficits found in the assessment of clinical populations such as Schizophrenia Spectrum Disorders (SSD). Fortunately, new methodologies have been developed which can isolate and measure these two cognitive traits independently within a single task referred to as a discrete whole-report WM task. Within the task, participants are presented with six colored squares during the initial memory array and must make responses about each item. This design allows for a more detailed assessment of memory performance (0-6 items recalled correctly) which can be used to determine an individual's complete memory performance on every trial. From this data, a computational model described in Hakim et al., (2020) determines an individual's maximum WM capacity and their sustained attention capacity, a measure of the probability with which a participant achieves their maximum WM capacity throughout the experiment. The present study administered a whole-report WM task to 26 individuals, 15 with SSD and 11 healthy age-matched controls. Our results suggest participants with SSD were significantly impaired in both sustained attention capacity and maximum WM capacity, though to a larger extent in their sustained attention capacity.

Moreover, removing trials where participants reported only 0 or 1 squares correctly significantly reduced differences in performance across the two groups in the whole report task. These results indicate that tracking and removing trials that reflect complete attentional lapses may provide more sensitive indices that better reflect true cognitive deficits.

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Switching target templates decreases search efficiency in efficient search

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According to Target-Contrast Signal Theory (TCST), parallel visual search unfolds via the active comparison of a search template held in mind and all stimuli in the search array. The aim of the comparison is to reject non-target items. Attention then scrutinizes the remaining non-rejected items. Previous studies on TCST focused on visual search tasks that had a fixed template throughout the experiment. Here, we studied how peripheral parallel search unfolds with varying templates. Following research by Carlisle, Arita, Pardo and Woodman (2011), we examined search with a target template that changed every five trials (a sequence). The targets were either a red triangle or a cyan semicircle. Target-distractor similarity was varied with two different kinds of distractors: orange diamonds or blue circles. Only one type of distractor was present on each trial. In addition, set size was varied to dissociate search processes (search slopes) and non-search (overall RT) processes. Consistent with TCST, results showed that RTs increased as a logarithmic function of set size, with larger logarithmic slopes in the high target-distractor similarity conditions than in the low target-distractor similarity conditions. Importantly, search efficiency varied as a function of position in the trial sequence. Regardless of target-distractor similarity, search slopes were steeper earlier in the trial sequence, suggesting that evidence accumulation rates were slower. In addition, response times for the target-only conditions were not affected by trial position, suggesting that switching target templates only impacted search related processes. Our findings extend Carlisle et al.'s results by showing that only search specific processes are impacted by the switching of target templates between sequences of trials in peripheral parallel efficient search.

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The new K on the block: working memory capacity estimates from a memory game

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Everyday cognitive processing employs working memory (WM), the ability to retain relevant information over a short period of time. The capacity of WM has been extensively debated, with standard answers in the range of 4 +/- 3 item. In naturalistic tasks, it has been reported that we choose to hold fewer items in memory, relying on the world as an external memory (Hayhoe et al, 1995, Draschkow et al., 2020). Here, we investigate how much WM capacity is utilized when we encourage, but do not require the use of available capacity. Participants played a version of the 'memory' or 'concentration' game. Participants turned over 'cards' in 6x4 arrays of cards. Each array held an unknown number of pairs (average ~6 pairs per array) and unique set of items. Participants could switch to a new array at will and collected 100 pairs as fast as possible to complete the task. A 15 second pause was imposed between arrays. In this version of the game, participants were alerted when the second member of a pair was uncovered. They then went back to find the first member of the pair as quickly as possible. We measured the number of clicks required to retrieve the first member of the pair. With perfect memory, participants would need just one click. Using no memory, participants could simply reclick each previously uncovered item until the target was found by chance (serial-self terminating search). Data from nine participants were consistent with imprecise memory for ~10 items, no doubt including some storage in longer term memory. Even though participants could have relied on the display as an external memory, they proved willing and able to use deploy more visuo-spatial memory than has been reported for other real-world tasks.

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Individual Differences in Working Memory Capacity Are Unrelated to the Magnitude

of Benefits from Object- and Dimension-Based Retro-Cues

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Previous studies have associated visual working memory (VWM) capacity with the ability to use internal attention. Internal attention's effect on VWM has been studied mostly using object-based retro-cues, which can direct internal attention to particular objects. In addition, by using dimension-based retro-cues recent studies have found that directing internal attention to a feature dimension in VWM can improve memory recall performance. Although the mechanism of object-based retro-cues has been studied for over ten years, no study to date has investigated the relationship between VWM capacity and the benefits of dimension-based retro-cues. The present study aims to explore individual differences in VWM capacity and their relationship with the use of dimension- and object-based retro-cues. We first measured participants' VWM capacity and then asked them to conduct a dimension-based cue task and an object-based cue task. We found that performed better than low-VWM-capacity participants in both dimension- and object-based cue tasks. In addition, although we identified certain RCBs obtained from both dimension- and object-based cues, we did not find any significant correlation between individual VWM capacity differences and the magnitude of the RCB obtained from object- or dimension-based cues. These results suggest that VWM capacity is not related to RCBs' magnitude, and thus VWM storage and the use of internal attention are independent mechanisms. Moreover, we found that the participants who benefitted the most from object-based retro-cues also benefitted the most from dimension-based retro-cues in color reports; however, this pattern was not found in the orientation report trials. This finding suggests a partly overlapping mechanism between the use of the two retro-cue types. The present study provides the first evidence of the relationship between VWM capacity and the dimension-based internal attention process.

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Just How Great are Those Expectations? Evaluating the Influence of Object-Color Violations on Visual Memory for Object-Shape

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Previously we assessed whether category expectations (e.g. object-color) that strongly-matched (e.g. yellow banana), weakly-mismatched (orangish-yellow banana), or strongly-mismatched (purple banana) study information boosted recall accuracy over information with no-expected match (yellow shirt). We found a boost in color recall accuracy for strong-matches suggesting prior expectations helped boost memory accuracy scores relative to mismatches or no-expectations. However, this past work was unable to shed insight on two hypotheses: (1) Error caused by the mismatch was offset by a surprisal memory boost, and (2) A simplified "least bits" coding mechanism (e.g. "off-yellow banana") was used for matches and weak mis-matches, allowing for easier encoding over strong-mismatches and no-matches. Here we assessed whether the limited boost of having object-color expectations on recall accuracy extends to other features of the object (e.g. object-shape). If in the prior study participants were using a "least bit" coding strategy when prior expectations exist, then shape memory may not suffer as much as no-expectation or mis-match. However, if color mismatches caused greater attention to overall object properties including shape, then color mis-matches should see improved shape memory relative to both no-expectation and expectation cases. Results revealed no significant differences between strong-match and either mismatches, with worse performance for no-expected matches. These results lend support that participants rely on prior expectations to simplify encoding, which are not available when prior knowledge cannot be leveraged. Interestingly, these results also support the surprisal boost hypothesis, suggesting that (at least in the context of color-object pairings) surprisal response in seeing a color-object mismatch triggers an increase in overall memory for object-shape matches over no-expectation conditions, but is not strong enough to out-perform the

boost gained by expectation matches. Thus, category expectations and surprise may play a role in how features of objects are bound together in visual memory.

Acknowledgements: This work was supported by NSF-SPRF 1911656 (KP), NSF SES-1627971 (EB) and the Jacobs Foundation (EB).

Revealing the Relative Contributions of Conceptual and Perceptual Information to Visual Memorability

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Visual Memorability has been shown to be an intrinsic property of images, yet it remains unclear what combination of image properties fully define visual memorability. We tested memory performance on the THINGS database (Hebart et al, 2019), a database of 26,107 images from 1854 different object categories, quantified by embeddings in a 49-dimensional space reflecting perceptual and conceptual components underlying human similarity judgments. We used these embeddings to examine image memorability in the context of this high dimensional object space. We carried out a continuous recognition task on 13,496 AMT participants, providing us with memorability scores for all images in the THINGS database. We observed significant consistency across participants' memory performance, allowing us to use memorability as an intrinsic attribute for each image. Our findings identified no significant correlation between memorability and ratings of typicality, suggesting that different images were memorable for different reasons. Correlations between the 49 dimensions and the memorability scores revealed that some dimensions (e.g. animal-relatedness) are more strongly associated with memorability than others (e.g. hardness). We capitalized on the nature of the dimensions as either perceptual or conceptual by focusing on relative contributions of perceptual and conceptual information to memorability. Using ratings of the dimensions along a scale from purely conceptual to purely perceptual, we analyzed the differences in correlation with memorability, variance in corrected recognition (hit rate – false alarm rate), and differences in raw embedding values between perceptual and conceptual dimensions. Our results indicated a stronger correlation with memorability for conceptual information than perceptual, where conceptual dimensions captured 31.72% of variance while perceptual dimensions only captured 6.07%. These results may indicate a greater contribution of conceptual information to the memorability of an image, suggesting a target for further study of the structure of visual memorability.

Retro-cue benefits are not resource-based

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Retro-cue paradigms show that we can prioritize some items in memory at the expense of other items. The most common explanation is that memory resources are reallocated from uncued to cued items. Here we test this popular theory by employing a working memory task with unequal item rewards to create uneven distribution of resources. Retro-cues then indicated that participants could remember cued items and drop uncued items from memory. If reallocation occurs, then we should observe a larger benefit when high reward items, which consume more resources, become irrelevant. Experiment 1 found that memory was better for items with higher reward values, $F(2,110)=15.00$, $p<.001$, and for valid versus neutral cues, $F(1,55)=22.60$, $p<.001$. However, dropping a higher reward item does not benefit performance more, $F(1,55)=0.19$, $p=.662$, inconsistent with reallocation. Experiment 2 replicated this null finding on a large data set ($n=100$) and with a higher memory load, and further showed that the disengagement of resources from a high versus a low reward item can benefit the encoding of a second array. Participants encoded two sequentially presented arrays. Items in the first array had unequal reward. Participants were later instructed to drop either high or low reward items from this array. A benefit for dropping high reward items was found when the cue was shown BEFORE the second array $t(99)=4.54$, $p<.001$, but not AFTER the array was already encoded, $t(99)=1.00$, $p=.321$ (interaction was $p=.030$). Thus, there was no benefit of removing high resource items for information already encoded into memory, but

there was a benefit for encoding new information. Together, these results suggest that retro-cues provide a benefit to stored information (e.g. due to protection or strengthening) that is, in contrast to the popular view, not linked to the withdrawal of resources from uncued items.

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The role of meaning in visual working memory: Real-world objects, but not simple features, benefit from deeper processing

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Recent studies have shown that visual working memory capacity is not fixed but varies by stimulus type: stimuli that are more meaningful are better remembered than meaningless simple features, such as colored squares (e.g., Brady et al., 2016). Here, we investigate which circumstances lead to the strongest memory benefits for meaningful stimuli, focusing on how different stimuli and memory displays are processed at encoding. In particular, we test the hypothesis that deeper, item-based encoding of objects increases the benefits for meaningful objects while encoding an entire set of items holistically and in parallel may reduce such benefits. Across four high-powered experiments (total N=280) we directly test whether real-world objects, perceptually-matched less-meaningful objects, fully scrambled objects, and colors benefit from deeper processing. We systematically vary the presentation format of stimuli at encoding to be either simultaneous — encouraging a parallel and holistic, 'take-a-quick-snapshot' strategy in which case items should be treated as meaningless colored shapes rather than distinct meaningful objects — or present the stimuli sequentially, promoting a serial strategy where each item is attended individually and processed in a high-level way. We find large advantages for meaningful objects in all conditions, but find that real-world objects — and to a lesser degree lightly scrambled, still meaningful versions of the objects — benefit from the sequential encoding and thus deeper, focused-on-individual-items processing, while colors do not. Our results suggest single feature objects such as colors may be an outlier in their affordance of parallel and holistic processing, and that in more realistic memory situations, visual working memory likely relies upon representations resulting from in-depth processing of individual objects (e.g., in higher-level visual areas) rather than solely being represented in terms of their low-level features.

Acknowledgements: This work was supported by an NSF grant (BCS-1829434) to TFB and VSS. We thank Kevin Sayed for help with data collection.

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The Visual Mandela Effect: Evidence for specific shared false memories in popular iconography

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The Visual Mandela Effect (VME) is an internet phenomenon describing shared and consistent false memories for specific images. For example, the mascot of the game Monopoly is falsely remembered as wearing a monocle although he never has. However, it has not been empirically tested whether certain images trigger the same false memory across observers. In this study, we characterize VME for images of highly familiar cultural icons. One hundred participants were presented with 40 images, each with three different variations: the original image and two manipulated versions. Manipulations included feature addition or subtraction, color changes, and orientation changes; some manipulations were previously identified in the "wild" as inducing VME. Participants were asked to choose the real version of images using their prior knowledge and rate their confidence in their choice and familiarity with the image concept. We identified seven images in which a specific manipulated image was chosen significantly more often than the correct or alternative manipulation. These choices were highly consistent across participants and, despite the low accuracy, participants rated their confidence and familiarity as medium to high. To determine what features of these images were important when making these real/fake judgments, we conducted a follow-up experiment using BubbleView (N=61), a method analogous to eye-tracking where mouse clicks imitate foveation by unblurring sections of a blurred image. Subjects who made erroneous judgments investigated the manipulated areas less than those who made correct judgments, suggesting that

VME is driven in part by a lack of attention towards these features. These results demonstrate that there are certain images for which people consistently make the same false memory errors, despite only having seen the veridical image. A closer examination of the nature of these errors might inform us about shared processes in how we represent or schematize information for memory.

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Visual Hindsight Bias for Mammogram Abnormalities in Expert Radiologists

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Hindsight bias – where people believe they can accurately predict something only once they know about it – is a pervasive decision making phenomenon, including in interpretation of radiological images (e.g., Berlin, 2000). However, some evidence suggests it is not only a decision making phenomena but also a visual perception one, where prior information about an image genuinely enhances our visual perception of that image (Harley et al. 2004). For example, the random image structure evolution (RISE) method of Sadr & Sinha (2004), where objects appear in random order embedded in different amounts of noise, demonstrates that primed images are genuinely recognized more easily than those that have not been seen before, a visual hindsight bias. The current experiment tests to what extent expert radiologists show a visual hindsight bias to mammograms with visible abnormalities when they are embedded in noise (e.g., to what extent they see the images differently when they know what the abnormality is, rather than just being biased at a decision level). N=40 experienced mammograph readers were presented with a series of unilateral abnormal mammograms (half had masses, half had calcifications), for three seconds each. After the presentation of each image, observers were asked to rate their confidence on a 6-point scale ranging from confident mass to confident calcification. Critically, we used the RISE method where the images in a sequence were repeated in an unpredictable order, and with varied noise. We found that radiologists who first saw a clear, original image were more accurate in the max noise level condition (d’=0.49) than those who first saw the degraded images (d’=0.20; p=0.017), suggesting that radiologists’ visual perception of medical images is enhanced by prior knowledge of the abnormality. Overall, these results provide preliminary evidence that radiologists experience not only decision level but also visual hindsight bias.

Multisensory Processing 3

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Retrospective Behavioral Sampling: A method to effectively track fluctuations in cognitive states during naturalistic audiovisual stimulation

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Our natural environment is dynamic. What perceptual and cognitive processes govern our continuously-changing natural experiences? A key challenge in the study of naturalistic perception is disentangling the multitude of perceptual and cognitive processes fluctuating simultaneously, without altering the ongoing natural experience. Here, we present a novel behavioral approach to track the dynamics of human experience retrospectively. This method of retrospective behavioral sampling models distinct dimensions of perception and cognition along the time-course of continuous audiovisual stimuli, without manipulating, simplifying or interfering with real-time natural perception. In the current study, 28 participants viewed short movies and listened to an auditory narrative. Audiovisual stimulation was followed by a questionnaire in which participants recalled their experience of more than 50 discrete events from the stimuli, measuring their quality of memory, magnitude of surprise, negative emotion, positive emotion, perceived importance, evoked introspection, and mental time travel. In addition, between 1 to 2 weeks after audiovisual stimulation, participants again rated their quality of memory for each of the sampled events. Results reveal highly reliable, and informative, temporal patterns of change in each of the measured cognitive states, exhibiting effective variability across events while maintaining consistency across individuals. Remarkably, memory ratings more than a week after stimulation resulted in an almost identical time-course of mean memorability across subjects, as was found immediately following stimulation.

Altogether, these findings validate the effectiveness of retrospective behavioral sampling in tracking fluctuations in cognitive states throughout naturalistic audiovisual stimulation, reliably across individuals and stably across measurements. We further discuss how these behavioral data can be used to identify discrete cognitive processes in neural patterns of response to the same audiovisual stimuli.

Acknowledgements: This work was supported by the Israel Science Foundation grant 1458/17 to Erez Simony.

Poster Session I > Multisensory Processing 3 > Poster I136

Unpredictive linguistic verbal cues accelerate congruent visual targets into awareness

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Does linguistic information speed up access to consciousness of matching visual information? This question was addressed by Lupyan & Ward (2013), and more recently by Forder, Taylor, Mankin, Scott, and Franklin (2016), and Ostarek and Huettig (2017). In these previous studies, however, target-congruency was either confounded with target predictability, or a paradigm was used that did not directly assess time-to-awareness. Here, we investigate whether congruent linguistic information speeds up access to awareness of matching visual information, using a breaking continuous flash suppression paradigm in which cue-target congruency was not confounded with predictability. In a speeded reaction time task, observers heard spoken color labels (e.g. red) followed by colored targets that were either congruent (red), incongruent (green) or neutral (a neutral non-color word) with respect to the labels. Importantly, and in contrast to previous studies investigating a similar question, the cues were never predictive of the targets. Our results show that RTs were selectively shortened for congruent verbal-visual pairings (and not lengthened for incongruent parings), and that this shortening occurred over a wide range of cue-target intervals. We suggest that linguistic verbal information pre-activates sensory representations, so that, for example, hearing the word 'tomato' pre-activates (visual) information internally, making it easier to spot tomatoes among other fruit in a fruit stall. Forder, L., Taylor, O., Mankin, H., Scott, R. B., & Franklin, A. (2016). Colour Terms Affect Detection of Colour and Colour-Associated Objects Suppressed from Visual Awareness. PLoS ONE, 11(3), e0152212–19. Lupyan, G., & Ward, E. J. (2013). Language can boost otherwise unseen objects into visual awareness. Proceedings of the National Academy of Sciences, 110(35), 14196–14201. Ostarek, M., & Huettig, F. (2017). Spoken words can make the invisible visible—Testing the involvement of low-level visual representations in spoken word processing. Journal of Experimental Psychology Human Perception and Performance, 43(3), 499–508.

Poster Session I > Multisensory Processing 3 > Poster I137

EEG signature of evidence integration suggests distinct visual and auditory representation in multisensory context

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Recent work in neuroimaging has highlighted that visual and auditory evidence integration can be tracked by the centroparietal positivity (CPP; O'Connell et al., 2012, Nature Neuroscience), an ERP component that echoes the ramping activity of neurons in the parietal cortex. While the CPP has been observed for both visual and auditory signals in separate tasks, it is unclear whether this component also reflects the integration of multisensory signals. 14 participants monitored a continuous stream of visual random dot motion and auditory tone clouds. The random dot motion consisted of 200 small dots displayed within a 7dva circular aperture, repositioned every 50ms. The tone clouds consisted of 10 simultaneous 50ms pure tones uniformly drawn from a range of 6 octaves (220 to 14080Hz) with a resolution of 12 semitones per octave. Participants had to detect the onset of a change from incoherent noise to a rising pattern of either coherently upward moving dots (unisensory visual), rising tone sequences (unisensory auditory) or simultaneous changes in both modalities (bimodal redundant). While participants performed the task, continuous EEG was acquired through 64 electrodes. The CPP could be observed above the centroparietal electrodes both in unimodal visual and auditory changes, and in bimodal redundant changes. Its slope predicted reaction times in the three

conditions, and, similarly to previous observations, it reached a stereotypical amplitude level leading to response execution. Additionally, the visual scalp projection of the CPP could be distinguished from its auditory equivalent by linear discriminant and single trial analyses, implying that visual evidence integration can be separated from its auditory equivalent. Altogether, our results suggest that the CPP can be extended to bimodal decision-making but also that visual and auditory signatures are distinct and can reveal idiosyncratic dynamics of visual and auditory dynamics of evidence integration.

Poster Session I > Multisensory Processing 3 > Poster I138

Decoding semantic sound categories in Early Visual Cortex

View Poster | Play Video | Visit me in Gather.Town Egret Room on Wednesday 8:00 am - 10:00 am EDT

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A high number of feedback connections links early visual cortex to several other cortical areas. Auditory cortex also sends feedback information to early visual cortex, but the content of this flux of information has not been fully explored yet. In a recent study by Vetter, Smith & Muckli (2014, Current Biology), it was found that feedback sent by auditory cortex is sufficient to produce distinguishable neural activity in early visual cortex when participants listen to different natural sounds in the absence of visual stimulation. The current study focused on understanding the information content of this flux of auditory feedback to visual cortex. We presented a sample of 36 sounds to 20 blindfolded participants while acquiring functional MRI data. Natural sounds were selected according to different semantic categories, e.g. animate sounds, divided into humans and animals, divided into specific species or types of sound, and the same for inanimate sounds. The boundaries of V1, V2 and V3 were drawn using individual retinotopic mapping. We analysed the fMRI activity patterns produced by these sounds in each early visual region using Multivoxel Pattern Analysis (MVPA). Results showed that the MVPA classifier could distinguish sounds belonging to different semantic categories on the basis of activity patterns in V1, V2 and V3. Particularly, animate sounds seemed to be generally better distinguished compared to inanimate sounds. Thus, auditory feedback to early visual cortex seems to follow some categorical distinctions, but not others. Our results show that auditory feedback relays certain categorical information to areas that were once believed to be exclusively specialised for vision. We hypothesise that early visual cortex may use this categorical information from sounds to predict visual input, enhance visual perception or to solve visual ambiguities.

Acknowledgements: This project was supported by a grant from the John Templeton Foundation (Prime Award No 48365) as part of the Summer Seminars in Neuroscience and Philosophy (SSNAP, subcontract No 283-2608).

Poster Session I > Multisensory Processing 3 > Poster I139

Statistical learning decreases sensitivity to temporal asynchrony of events within as well as across modalities

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Co-association of an auditory and a visual event due to frequent co-occurrence have been reported to increase the size of their temporal binding window, that is the range of asynchronicity between the onset of the two events at which observers perceive them occurring simultaneously. According to a probabilistic interpretation, co-occurrence strengthens the prior that the two events originate from a common cause resulting in a higher degree of perceptual integration across modalities despite contradicting sensory evidence. However, statistical learning creating associations is considered to be a domain-general mechanism and as such, it should facilitate similar integration within a single modality as well, where distinctiveness of the two modalities cannot help. Using a simultaneity judgement task, we tested this conjecture by examining the change of observers' sensitivity to asynchrony after implicit learning of co-occurrences within the visual modality. In a learning phase (LP), observers saw arbitrary shape-pairs moving synchronously in a random direction. In the test phase, three types of pairs were presented: 1) visual pairs seen during the LP, 2) pairs from the LP in a new combination, 3) pairs with completely new shapes. The asynchrony between the movement onset of the elements was manipulated. Observers showing learning during LP (N= 24) reported a higher proportion of simultaneity judgments, as

quantified by higher temporal binding windows for the learned pairs than for the newly combined or novel visual pairs ($p < 0.05$) indicating an increased probability of unisensory integration despite identical sensory evidence. Thus, prior experience of high co-occurrence alters the perceived relation of elements in time within a single modality the same way as it does across modalities. These results point to a general mechanism of sensory binding across the entire spectrum of sensory input space.

Integration of visual and haptic texture information: Lederman & Abbott revisited

View Poster | Visit me in Gather.Town Egret Room on Wednesday 8:00 am - 10:00 am EDT

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We partially replicated and extended a study by Lederman and Abbott (1981, J Exp Psycho, 7(4), 902-915) who found that visual and tactile modalities contributed approximately equally to the visuo-tactile perception of surface texture. In a discrepancy paradigm, participants picked from sandpapers with grit values ranging from 40 (coarse) to 220 (fine) matches to visual (150 grit), tactile (60 grit), or discrepant visuo-tactile (150 & 60 grit) standards using vision, touch, or both modalities simultaneously (nine matches per participant). In our first experiment (N=12), we replicated Lederman and Abbott's first experiment using a within-subjects design, instead of their between-subject design, to be able to evaluate interindividual differences in modality weights. Participants performed nine matches in separate sessions. In the second experiment, a subset of the same participants (N=10), repeated the first experiment but with the visual stimuli being illuminated from the side instead of from the top resulting in a modified appearance of the same visual stimuli. The first experiment showed that, on average, visual and haptic modalities contributed approximately equally to the visuo-tactile percept. This replicated the findings of Lederman and Abbott. We found considerable interindividual variations in the weights. Only two participants had almost equal weights while half of the others had higher visual and half had higher tactile weights. In the second experiment, we found similar average weights as before but the individual weights were consistently closer to equal modality weights. The grazing illumination increased the perceived coarseness of the visual stimulus and thus reduced the discrepancy between visual and tactile stimuli resulting in more consistent information. Our results demonstrate that visual and tactile information are weighted equally within a certain range of discrepancy. Outside this range, one of the modalities is weighted higher with no clear preference for either the visual or tactile modality.

Acknowledgements: This work was supported by the Biotechnology and Biological Sciences Research Council (BBSRC).

Influence of tactile flow on visual heading perception

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The integration of information from different sensory modalities is crucial for successful navigation through an environment. For example, self-motion produces distinct optic flow patterns on the retina, vestibular signals and tactile flow, which help to determine travelled distance or heading direction. We recently showed that visual and tactile information interact in a path integration task (Churan et al., J.Neurophysiol., 2017). Responses had higher precision in a bimodal as compared to unimodal conditions. Here, we investigate the influence of task-irrelevant tactile flow on visual heading perception. We simulated self-motion across a ground plane in different forward directions. Visual stimuli (optic flow) covered the central 81° x 66° of the visual field. Tactile stimuli were delivered by air flows from head-mounted nozzles. In a block of trials, tactile and visual stimuli were presented simultaneously for 500 ms, either simulating congruent heading or with an offset of the tactile flow within +/-40° of the visual heading. Participants had to report the perceived visual heading. In two other blocks of trials, subjects performed the heading task for purely visual or tactile stimuli. Heading in both, the bimodal and the two unimodal conditions, revealed a central bias, i.e., heading directions were perceived as compressed towards straight-ahead. Combination of congruent visual and tactile heading cues did not result in an improved precision of heading estimates as compared to the unimodal conditions, indicating non-optimal

signal integration in a Bayesian sense. Nevertheless, we found a systematic influence of tactile heading cues on visually perceived headings if the headings represented by the two modalities were closer than 16°. In such case, visual heading perception revealed a significant bias towards the behaviorally irrelevant tactile heading. The spatial properties of multisensory neurons in the functional equivalent of macaque area VIP in humans are compatible with our results.

Acknowledgements: Deutsche Forschungsgemeinschaft (SFB/TRR-135 project number: 222641018, A2 and IRTG-1901)

Poster Session UG-A

Undergraduate Just-In-Time Posters 1

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A1

Familiar Size Reliably Affects Size and Distance Perception in High-Resolution Virtual Reality

View Poster | Visit me in Gather.Town Flamingo Room on Sunday 8:00 pm - 10:00 pm EDT

Kieran Hussey[1] (kieranhussey@hotmail.com), Jody C. Culham[2], Laurie M. Wilcox[3]; [1]Western University 1,2, [2]York University 3

Previously, our lab found that size and distance perception in virtual reality (VR) is determined primarily by the familiar size of objects under monocular and binocular viewing conditions (Rzepka, V-VSS 2021). Here we examined: 1) whether the familiar size effect generalizes to diverse objects; and 2) whether binocular viewing has more influence when using a state-of-the-art VR headset (Varjo XR1).

Acknowledgements: Advisors/Mentors: Dr. Jody Culham & Dr. Laurie Wilcox. Funding: Natural Sciences and Engineering Research Council (Canada), New Frontiers in Research Fund (Canada), Western University.

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A2

Perceived visual similarity between scenes influences behavioural discrimination in an observer-specific manner

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Pratishtha Sharma[1] (pshar29@uwo.ca), Kayla M Ferko[1], Stefan Köhler[1]; [1]Brain and Mind Institute, University of Western Ontario, London, Ontario, Canada

Links between subjective characteristics of perception and interindividual differences in behaviour remain poorly investigated at present. Recent work from our lab revealed that perceived visual similarities between exemplars of real-world object categories influence discrimination performance in an observer-specific manner. In the current study, we aimed to determine whether such observer-specific similarity effects are also present in visual discrimination of scenes.

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A3

Perceptual Comparisons Induce Varying Forms of Memory Updating

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Zoryana Babiy[1], Keisuke Fukuda[1], Joseph Saito[2]; [1]University of Toronto Mississauga, [2]University of Toronto

During perceptual comparisons, perceived similarity between a visual working memory (VWM) and novel visual probe triggers representational integration that manifests in biased memory reports. Here, we tested the hypothesis that a VWM may be replaced by a novel probe instead when the two are perceived to be the same rather than similar, reflecting a qualitatively distinct type of memory distortion.

Acknowledgements: This work was supported by an NSERC Discovery Grant awarded to KF (RGPIN-2017-06866).

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A4

Prevalence effects on the road: Rare hazards are often missed

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Simran Kanda[1] (simrankandaa@gmail.com), Anna Kosovicheva[1], Benjamin Wolfe[1], Jeremy M. Wolfe[2,3]; [1]University of Toronto Mississauga, [2]Brigham & Women's Hospital, [3]Harvard Medical School

Detecting hazards on the road is a complex perceptual task, requiring fast and accurate responses. Our ability to detect these dangers may depend on their prevalence, or how frequently they occur. Research in visual search has shown that rare events are often missed, but it is unknown whether these effects extend to dynamic real-world scenes like driving.

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A5

Sleep Quality and its Links to Attention

View Poster | Visit me in Gather.Town Flamingo Room on Sunday 8:00 pm - 10:00 pm EDT

Ashley C Steinkrauss[1] (asteinkr@conncoll.edu), Jeff Moher[1]; [1]Connecticut College

In this study, we want to understand the effects of sleep on attention, specifically with the use of the gradual onset continuous performance task (gradCPT) and the additional singleton task (AS).

Acknowledgements: Special thanks to the Rena Rimsky Wing '67 Endowed Fund for Psychology Student Research.

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A6

Sound-induced Flash Illusion in Forced-choice and Go/No-Go Tasks

View Poster | Visit me in Gather.Town Flamingo Room on Sunday 8:00 pm - 10:00 pm EDT

Gabriel J Wooten-Soto[1] (gabriel.wooten-soto@mail.mcgill.ca), Stephen G Lomber[1]; [1]McGill University

The sound-induced flash illusion (SIFI), the misperception of flash number when presented with an incongruent number of clicks, has been studied almost exclusively using a forced-choice task. Compared to forced-choice tasks, Go/No-Go tasks remove the need for response selection. Understanding the audiovisual interaction under different cognitive loads will pave the way for studies in different development trajectories (e.g. cochlear implant).

Acknowledgements: The funding was made possible by the Canadian Institutes of Health Research.

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A7

Strategy instruction boosts visual search optimality but such improvements transfer poorly to similar tasks

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Vaibhav Khandelwal[1] (khandelwal.34@osu.edu), Andrew Leber[1], Molly McKinney[1], Walden Li[1], Jessica Irons[1]; [1]The Ohio State University

When searching for a target in the visual scene, such as for your red car, performance depends on the strategy chosen (e.g., searching for red things vs. things with wheels), and research has revealed widespread suboptimality of strategy. Explicit strategy instruction can improve choice, but can the improvement generalize across separate tasks that retain similar strategy components?

Acknowledgements: NSF BCS-2021038 to ABL

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A8

The effect of auditory feedback on perceptual and oculomotor performance in a gaze-contingent simulated scotoma paradigm

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Katherine Costa[1] (costa.k@northeastern.edu), Jan Skerswetat[1], Peter J. Bex[1], Nicole Ross[2]; [1]Northeastern University, [2]New England College of Optometry

Gaze-contingent simulated scotomas have been used in normally-sighted individuals to mimic central-vision-loss(CVL) and to study perceptual and ocular-motoric processes.We investigated the effect of audio feedback on eccentric viewing training assessed with fixation stability(Bivariate Contour Ellipse Areas, BCEAs), contrast sensitivity functions(CSF), Area-Under-the-Curve(AUC), and acuity(highest visible spatial-frequency).

Acknowledgements: Supported by NIH grant R01 EY029713

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A9

Using Functional Near-Infrared Spectroscopy for the Study of Visually Guided Hand Actions

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Homa Vahidi[1] (hvahidi2@uwo.ca), Guy Rens[1], Bettina Sorger[2], Jody C. Culham[1]; [1]University of Western Ontario, Canada, [2]Maastricht University, Netherlands

The neuroscientific study of visually guided actions has been hampered by the reliance on techniques, primarily functional magnetic resonance imaging (fMRI), that constrain bodily movements. Therefore, we examined the feasibility of using functional near-infrared spectroscopy (fNIRS) to study hand actions using a modified paradigm previously employed with fMRI (Cavina-Pratesi et al., 2018, Cortex).

Acknowledgements: Natural Sciences and Engineering Research Council (Canada), Canada First Research Excellence Fund BrainsCAN, Canadian Institutes of Health Research

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A10

Discomfort from Contemporary Art: Contribution of Color

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Xortia Ross[1] (xortia_ross@nevada.unr.edu), Sarah M Haigh[1], Olivier Penacchio[3], Arnold J Wilkins[2]; [1]University of Nevada, Reno, [2]University of Essex, Colchester, England, [3]University of St Andrews, Scotland

Images that evoke visual discomfort tend to deviate from the 1/f relationship commonly revealed by the Fourier amplitude spectrum of images from the natural environment. However, this ignores the contribution of color. We focused on the effect of chromaticity difference on discomfort by using contemporary non-representational works of art that varied in both structural complexity and in color.

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A11

Emotion recognition of perceived genuine or posed expressions using web-based eye tracking

View Poster | Visit me in Gather.Town Flamingo Room on Sunday 8:00 pm - 10:00 pm EDT

Tahirih Altair[1], James Tanaka[1], Amy Dawel[2], Amy vanWell[3]; [1]University of Victoria, [2]The Australian National University

In everyday life emotions may be genuine (e.g. smiling at a loved one) or posed (e.g. smiling to be polite). The current study investigates how perceived sincerity influences emotion recognition. A collection of naturalistic expressions was used, taken from real-world media and normed for perceived genuineness. Gazer, a web-based eye tracking software, was used to record gaze during the trials.

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A12

Evaluating faces and bodies: Does body information influence face perception?

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Katelyn Forner[1] (katelynforner13@gmail.com), James Tanaka[1], Isabella Schopper[1]; [1]University of Victoria

In face perception, the composite-face effect has demonstrated that holistic processing is disrupted when top and bottom face halves are aligned relative to when the halves are misaligned. In the current study, a face-body composite task was employed to test whether body information influences face perception and whether a possible body effect is holistic or analytic.

Acknowledgements: This study was funded by NSERC under the supervision of Dr. James Tanaka.

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A13

Investigating the Effects of Orthography, Neighborhood Density, and Frequency on Single Word Recognition in a Visual Search Task

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Olivia Longpre[1] (olongpre@shaw.ca), James Tanaka[1], Ipek Cukurova[1], Amy vanWell[1]; [1]University of Victoria

In the current study, we investigated single word recognition in a visual search task employing eye-tracking and reaction time measures. The target item was a real word that was shown amongst pronounceable or non-pronounceable distractor words. The target and distractor words varied in their neighbourhood density (dense versus sparse) and word frequency (high versus low).

Acknowledgements: This study was funded by NSERC through the supervisor Dr. James Tanaka.

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A14

Investigating the Time Course of Face Perception Using Web-based Eye Tracking

View Poster | Play Video | Visit me in Gather.Town Flamingo Room on Sunday 8:00 pm - 10:00 pm EDT

Amy vanWell[1] (amyvanwell@gmail.com), James Tanaka[1], Xiaoyi Liu[2], Jacob Martin[3]; [1]University of Victoria, [2]New York University - Abu Dhabi Campus, [3]Georgetown University

The recent evolution of personal laptop cameras and eye-tracking software have created an opportunity to expand web-based science to include eye-tracking. The Gazer Program developed at the University of Victoria implements the essential measures of in-person eye-tracking on a laptop device using the open-source Webgazer software. The current study investigates the Gazer capabilities in a visual search task with faces.

Acknowledgements: This study was funded by NSERC through the supervisor Dr. James Tanaka.

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A15

Monocular Deprivation: Ocular balance shift or mere contrast adaptation?

View Poster | Visit me in Gather.Town Flamingo Room on Sunday 8:00 pm - 10:00 pm EDT

Sharon C. Y. Lo[1], Dorita H. F. Chang[1,2]; [1]Department of Psychology, The University of Hong Kong, Hong Kong, [2]The State Key Laboratory of Brain and Cognitive Sciences, The University of Hong Kong, Hong Kong

Previous work has indicated that short-term monocular deprivation leads to an all-or-none shift of sensory eye dominance (SED) towards the deprived eye. Here, we investigated whether short-term monocular-deprivation-induced shifts in SED can be explained, at least in part by mechanisms of simple contrast adaptation.

Acknowledgements: Funding: Guangdong-Hong Kong-Macau Greater Bay Area Brain Science Research Center, Open Research Grant, China (2019006).

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A16

No evidence for gender and cultural differences in eye movements – a meta-analysis

View Poster | Visit me in Gather.Town Flamingo Room on Sunday 8:00 pm - 10:00 pm EDT

Charlotte Hood[1] (charlotte.hood@mail.utoronto.ca), Dirk B. Walther[1]; [1]Department of Psychology, University of Toronto

Analyzing data by ethnicity and/or gender is not common in eye-tracking studies. Though this practice was initiated as a response to discrimination, it preempts the recognition of group differences and thus impedes psychological research. This study seeks to assess the state of the literature and provide insight as to whether ethnicity and gender warrant further investigation.

Acknowledgements: NSERC Discovery Grant RGPIN-2015-06696.

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A17

Postural and kinematic contributions to expertise identification in yoga

View Poster | Play Video | Visit me in Gather.Town Flamingo Room on Sunday 8:00 pm - 10:00 pm EDT

Sophia Baia[1] (srbaia@g.ucla.edu), Hongjing Lu[1], Akila Kadambi[1]; [1]University of California, Los Angeles

Previous studies highlight the importance of expertise and kinematics in the perception and identification of biological motion in active sports. In contrast to traditional sports' focus on kinematics, yoga involves real-time integration and awareness of postural states during movements. The current study assessed the relative contributions of kinematics and posture to expertise identification based on individual variability in yoga experience.

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A18

Preference of Facial Attractiveness is 'heritable' within the Family

View Poster | Visit me in Gather.Town Flamingo Room on Sunday 8:00 pm - 10:00 pm EDT

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Studies found that parents' facial features can predict children's facial features genetically. In addition, both parents and daughters are more likely to choose attractive men as their daughters' mates, possibly because facial attractiveness preference also has a genetic role. Therefore, this study explores whether parents' facial attractiveness preference has a genetic predictive effect on children's facial attractiveness preference.

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A19

Real World Objects in the Attentional Blink

View Poster | Visit me in Gather.Town Flamingo Room on Sunday 8:00 pm - 10:00 pm EDT

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The temporal limits of attention are illustrated by the attentional blink (AB), where attending to a second target in an RSVP stream becomes difficult 200-500 milliseconds after attending to an initial target. Here we focus on the nature of the loss of target information in the AB for realistic objects, asking whether this loss is discrete or graded.

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A20

Serial dependence in biological motion perception

View Poster | Visit me in Gather.Town Flamingo Room on Sunday 8:00 pm - 10:00 pm EDT

Yongqi Li[1] (liyq98@mail2.sysu.edu.cn), Xiaowei Ding[1], Jiayu Qian[1], Zhou Su[1], Huichao Ji[1]; [1]Sun Yat-sen University, Guangzhou, China

Serial dependence refers to the perception bias of the current stimulus towards the previous one, which has been widely found in studies of low-level physical stimuli. Apart from physical information, perceiving biological motion is also crucial for human survival. In this study, we investigated is there serial dependence when we perceive biological motion and whether this effect is cross-level (physical-social).

Acknowledgements: This research was supported by College Students' Innovative Entrepreneurial Training Plan Program to Li Yongqi.

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A21

The neural correlates of sensory eye dominance as revealed by visual white matter tract properties

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Ailene Y. C. Chan[1] (chanyca@hku.hk), Dorita H. F. Chang[1,2]; [1]Department of Psychology, The University of Hong Kong, Hong Kong, [2]The State Key Laboratory of Brain and Cognitive Sciences, The University of Hong Kong, Hong Kong

Sensory eye dominance (SED) refers to the preferential processing of information from one eye versus another. Theoretical models have suggested that SED results from interocular gain-control before and/or after binocular summation. Here, we investigated the relationship between visual white matter tract properties and SED in healthy vision.

Acknowledgements: Guangdong-Hong Kong-Macau Greater Bay Area Brain Science Research Center, Open Research Grant,

China (2019006)

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A22

Visual Communication of Object Concepts at Different Levels of Abstraction

View Poster | Visit me in Gather.Town Flamingo Room on Sunday 8:00 pm - 10:00 pm EDT

Justin Yang[1] (justin-yang@ucsd.edu), Judith Fan[1]; [1]UC San Diego

People can produce drawings of specific entities (e.g., Garfield) as well as abstract categories (e.g., “cat”). What explains this ability to produce drawings at different levels of abstraction? We hypothesize that this ability is jointly dependent on sensory information and representational goals, such that drawings of just-seen exemplars contain different semantic information than drawings of an abstract category.

Acknowledgements: We thank UC San Diego's Academic Enrichment Programs and the Halıcıoğlu Data Science Institute for supporting this research.

Poster Session UG-A > Undergraduate Just-In-Time Posters 1 > Poster UG-A23

Navigating distractors in the new normal world: An investigation of selective attention and social facilitation in the online environment

View Poster | Play Video | Visit me in Gather.Town Flamingo Room on Sunday 8:00 pm - 10:00 pm EDT

Karishma Dave[1] (kxd873@student.bham.ac.uk), Wieske van Zoest[1]; [1]University of Birmingham, UK

COVID-19 social distancing measures have necessitated a rapid digital transformation of important everyday activities. The current study aimed to investigate 1) the effects of the online environment on visual search performance, and 2) whether virtual social presence elicited social facilitation, possibly benefitting attentional selection. We explored whether attentional and socio-communicative atypicalities common of Autism Spectrum Disorder would moderate these effects.

Acknowledgements: Thanks to Ashleigh Bazeley, Anjali Nayer, Rhiannon Pierce, Nia Rees, and Makayla Ward for support and collaboration on design and data collection of this project.

Poster Session UG-B

Undergraduate Just-In-Time Posters 2

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B1

Masking the smeared perception of natural scenes tachistoscopically presented during saccades: A follow-up on Campbell & Wurtz (1978).

View Poster | Play Video | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Mara Doering[1] (maradoe96@gmail.com), Richard Schweitzer[1], Martin Rolfs[1]; [1]German

Each saccade that we make results in high-velocity image shifts on the retina, inducing large-field motion blur, so-called intra-saccadic smear. Campbell & Wurtz (1978) showed that stable pre- and post-saccadic retinal images are sufficient to eliminate the percept of a smeared image. Here we investigated post-saccadic masking of intra-saccadic smear induced by a wide range of natural scenes.

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B2

Motor affordances in visual search for multiple targets

View Poster | Play Video | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Anastasia Ahufrieva[1] (aanufrieva@hse.ru), Elena Gorbunova[1]; [1]HSE University

Affordance is a property of an object, that defines the possible action with it. The goal of current study was to reveal whether a congruence of action with object impacts accuracy and reaction time in visual search. The study investigated the subsequent search misses (SSM) effect - the decrease in accuracy of second target detection after finding the first target.

Acknowledgements: The research was supported by RSCF grant № 20-78-10055

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B3

Probing human 3D shape perception with novel, but natural stimuli

View Poster | Play Video | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Kira I. Dehn[1], Roland W. Fleming[1,2], Guido Maiello[1]; [1]Justus Liebig University Giessen, Germany, [2]Center for Mind, Brain and Behavior (CMBB), University of Marburg and Justus Liebig University Giessen , Germany

We easily tell apart a cereal bowl from a coffee cup. To which extent does this ability rely on how we visually perceive 3D shape, rather than higher level cognitive constructs such as object affordances (e.g. a cup has a handle)? The aim of the current study was to probe human 3D shape perception independently of cognitive constructs.

Acknowledgements: This work was supported by the Deutsche Forschungsgemeinschaft (SFB-TRR-135: "Cardinal Mechanisms of Perception," Project 222641018) and a European Research Council Consolidator Award (ERC-2015-CoG-682859: "SHAPE").

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B4

The Effect of Emotion on Generalising Trustworthiness

View Poster | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Zara Yahya[1] (zara.yahya97@gmail.com), Dr Miflah Hussain[1]; [1]University of Nottingham Malaysia

Trustworthiness is an attribute that we generalise from one person to another. Feldman-Hall et al. (2018: PNAS, 115(7)) found that people often trust strange faces that closely resemble a known trustworthy identity and avoid interactions with those who closely resemble a known untrustworthy identity. This study examined how emotional expressions affect generalisation of trustworthiness from one face to another.

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B5

The Sabancı University Dynamic Face Database (SU DFace)

View Poster | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Mahnoor Nadeem[1] (mahnoornadeem@sabanciuniv.edu), Nihan Alp[1], Yağmur Damla Şentürk[1]; [1]Sabanci University

Although faces are highly dynamic, most face databases consist of either static stimuli or the dynamicity is derived from emotional expressions. Here, we present the development and validation of the Sabancı University Dynamic Face database, in which extraction of dynamicity without the influence of emotional processes is possible as it only contains neutral facial expression and natural speech articulation.

Acknowledgements: This research was supported by the Starting Grant from Sabancı University (B.A. CG-19-01966) to Nihan Alp.

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B6

A multiple regression model of social processing during naturalistic movie viewing

View Poster | Play Video | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Lucy Chang[1], Haemy Lee Masson[1], Leyla Isik[1]; [1]Johns Hopkins University

The real social world is multimodal, dynamic, and contextually embedded. Yet, most social vision studies utilize simple stimuli that do not capture the complexity of the real social world. Thus, we investigated naturalistic social cognition using a movie viewing paradigm to improve ecological validity and better emulate the social context available in the real world.

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B7

A potential role for binocular integration without binocular disparity information in primary visual cortex

View Poster | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Ethan S. Cheng[1] (echeng21@umd.edu), Daniel A. Butts[1]; [1]University of Maryland, College Park

How information from both eyes aligns in the primary visual cortex (V1) depends on the vergence of the eyes and the depth of a given object, resulting in a particular binocular disparity. However, a significant fraction of V1 neurons are binocular but not modulated by binocular disparity, raising the question of how their outputs can be meaningful.

Acknowledgements: This work was supported by the NSF IIS-1350990.

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B8

Adults' recognition of newly learned faces: The effect of within-person variability in appearance after a long-delay

View Poster | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Emily McLaughlin[1], Margaret Moulson[1]; [1]Ryerson University

Recognizing faces is a critical part of social interactions. However, facial appearance changes naturally depending on factors such as lighting and viewpoint and these variations can pose a challenge for successful recognition, particularly of unfamiliar faces. The objective of our study is to examine how natural variability in appearance during learning influences face recognition after a one week delay.

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B9

Binocular Disruption in Amblyopia Investigated with Standardized Clinical Tests and FInD-Psychophysics

View Poster | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Nicolas Aycardi[1] (n.aycardi.c@gmail.com), Jan Skerswetat[1], Peter J. Bex[1], Shahin Nasr[2]; [1]Northeastern University, [2]Harvard Medical School

Amblyopia, a developmental neuro-visual disorder, impairs some tasks (acuity, contrast-sensitivity, stereoacuity) but may spare others (color). We investigated monocular and binocular processing in eight amblyopic and normally-sighted adults using standardized clinical tests and FInD-psychophysics to investigate binocular disruption.

Acknowledgements: NA, JS and PB were supported by NIH grant R01 EY029713. FInD is protected by a provisional patent that is owned by Northeastern University, Boston, USA.

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B10

Can You Break the Tyranny of Film?: The power of viewers’ film genre preferences and knowledge on attentional selection

View Poster | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Isabella Hubbell[1] (isabellahubbell250@ksu.edu), Taylor Simonson[1], Lester Loschky[1]; [1]Kansas State University

Filmmakers employ bottom-up techniques to guide viewers’ attention, producing attentional synchrony between viewers, even if comprehension differs. However, certain top-down factors (e.g., task) influence attention in film. Furthermore, research shows 1) genre preferences affect attention to product placement in movies, and 2) genre preferences vary by demographics. Thus, do divergent demographic-based genre preferences affect viewers’ attention during film viewing?

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B11

Changes in Cortical Activity in a Parkinson's Disease Patient: Effects of Training with Visual and Auditory Cues

View Poster | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Royze Simon[1] (royze25@my.yorku.ca), Joseph Desouza[1]; [1]York University

Studies have demonstrated that external rhythmical cues improve gait and balance in PD patients. Moreover, there is evidence to support that other forms of external cues and stimuli such as visual and somatosensory are also effective. This study thus aimed to investigate the effects of long-term training that combine visual and auditory cues in a patient with Parkinson’s disease.

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B12

Comparisons with Similar Faces Induce Lasting Distortions in Face Memories

View Poster | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Jerrick Teoh[1] (jerrick.teoh@mail.utoronto.ca), Joseph M. Saito[2], Keisuke Fukuda[1,2]; [1]University of Toronto Mississauga, [2]University of Toronto

Recent studies have demonstrated that simple visual working memory (VWM) representations (e.g., colors, shapes) are systematically biased during comparisons with similar perceptual inputs. Here, we tested whether this memory bias occurs with more complex visual stimuli (i.e., faces) that enter VWM via perceptual encoding or long-term memory (LTM) retrieval.

Acknowledgements: This research was supported by the Natural Sciences and Engineering Research Council (RGPIN-2017-06866) awarded to KF.

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B13

Effects of Neuronal Excitability Parameters on Spiking RNN Activity

View Poster | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Amelia Simonoff[1] (asimonoff@uchicago.edu), David Freedman[1]; [1]University of Chicago

Exactly how memories are stored in the brain is still an open question, of which neuronal excitability is an important part. The purpose of our research was to determine to what degree each excitability parameter affects memory encoding, and to determine how the different mechanisms of excitability modulation could mediate a competitive form of memory allocation.

Expertise predicts perceived visual similarity between exemplars of real-world object categories

View Poster | Play Video | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Alexander N. Minos[1] (aminos@uwo.ca), Kayla M. Ferko[1], Stefan Köhler[1]; [1]Brain and Mind Institute, University of Western Ontario, London, Ontario, Canada

Observers perceive their visual environment in unique ways. Ferko et al. (2021) recently reported that the perceived visual similarity among exemplars of real-world categories differs across observers in ways that influence discrimination behaviour. What observer characteristics mediate this variability across individuals remains poorly understood. We hypothesized that category-specific expertise predicts the perceived similarity ratings among object exemplars in these categories.

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B15

Exploring the mental representation of observed grasp movements based on similarity judgements

View Poster | Play Video | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Leah J. Ettensohn[1] (ettensohnlj@nih.gov), Maryam Vaziri-Pashkam[1], Kristin Woodard[1], Leslie G. Ungerleider[1], Chris I. Baker[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health

Hand grasp movements are frequent during our everyday activities. When encountering a moving hand aiming at an object, we are able to quickly recognize the grasp movement and characterize it. Here we aim to: 1) Determine how well humans can identify the object of a grasp based on observing grasp movements, and 2) Identify the core dimensions underlying these judgements.

Acknowledgements: Intramural Research Program of NIMH

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B16

Flanker task under (perceived) time pressure

View Poster | Play Video | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Rachel Sussman[1] (rfreedsussman@brandeis.edu), Robert Sekuler[1], Mercedes Villalonga[1], Hannah Snyder[1]; [1]Brandeis University

In everyday life, time pressure impacts executive function (EF); in the laboratory, Eriksen's Flanker task assays EF's perceptual effects. Previous work with the Flanker task found that manipulating time pressure by restricting response windows disrupts EF. Would perceived (rather than objective) time pressure have a similar outcome?

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B17

InFoRM (Indicate-Follow-Replay-Me): Rivalry generates individual, validated introspection maps and generates new insights in binocular rivalry dynamics

View Poster | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Hanley Jefferis[1] (jefferis.h@northeastern.edu), Jan Skerswetat[1], Peter J. Bex[2]; [1]Northeastern University

Dissimilar images can generate perceptual competition (binocular rivalry) classically measured with subjective reports among 2-4 pre-defined states(OS,OD,piecemeal,and superimposition). To validate estimates of introspection, increase measurement resolution, and monitor visual consciousness dynamics, participants moved a joystick in four phases: 1.Indicate then 2.Follow physical images, 3. Measure endogenous dichoptic-rivalry, and 4.Replay those rivalry-changes via physical images.

Acknowledgements: Supported by NIH grant R01 EY029713. InFoRM is protected by a provisional patent that is owned by Northeastern University, Boston, USA.

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B18

Investigating distributed functional connectivity during word and nonword visual recognition

View Poster | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Raina Vin[1] (rvin@andrew.cmu.edu), Marlene Behrmann[1], Nicholas M. Blauch[1]; [1]Carnegie Mellon University

Functional magnetic resonance imaging (fMRI) studies have repeatedly demonstrated that word recognition is associated with activation of the Visual Word Form Area (VWFA) in the left hemisphere (LH). We investigate the question: what other regions in both the right and the left hemispheres are engaged in reading, and how do they synergistically interact with the VWFA to enable word recognition?

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B19

Neuronal encoding of rapid categorical decisions across the primate oculomotor network

View Poster | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Suha Chang[1], David J. Freedman[1], Oliver Zhu[1]; [1]University of Chicago

Our ability to rapidly categorize stimuli can significantly influence our decisions. For instance, professional table tennis players must categorize trajectories of incoming balls within ~400ms to successfully adjust their paddles' motion. Though previous studies have examined the oculomotor system's role in visual categorization, few have explored this process when ongoing motor plans are rapidly modulated by incoming, relevant sensory information.

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B20

Using Biological Motion to Perceive Human Movement During a Remote Task

View Poster | Play Video | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Jeffrey Kelly[1] (jeff.kelly71@gmail.com), Michael Cinelli[1], Sheryl Bourgaize[1]; [1]Wilfrid Laurier University

Biological motion research suggests point-light display (PLD) can be used to demonstrate human walking profiles. However, little is known regarding the body segment information that affords individuals perceptual accuracy of approaching individuals. Therefore, we investigated whether individuals could use PLD to make accurate anticipatory decisions about future travel paths of an approaching humanoid and which body segments were most informative.

Acknowledgements: Funding support through the Natural Sciences and Engineering Research Council (NSERC) of Canada is gratefully acknowledged.

Poster Session UG-B > Undergraduate Just-In-Time Posters 2 > Poster UG-B21

Weather Discrimination in Scene Processing Regions

View Poster | Visit me in Gather.Town Flamingo Room on Tuesday 8:00 am - 10:00 am EDT

Tess Durham[1] (tdurham1@fordham.edu), Elissa Aminoff[1]; [1]Fordham University

Scenes are complex visual images. Previous studies have found brain regions, including the parahippocampal place area (PPA), retrosplenial cortex (RSC), and occipital place area (OPA) to be associated with scene processing. Weather is a feature not yet considered to modulate scene processing in the brain. This study aims to understand to what extent weather affects the representation within these regions.

Acknowledgements: Fordham University Undergraduate Reseach

Satellite Events

An introduction to TELLab - The Experiential Learning LABoratory, a web-based platform for educators

Saturday, May 22, 8:00 - 9:00 am EDT, Sea Turtle **Join Zoom Webinar**

Sunday, May 23, 6:00 - 7:00 pm EDT, Sea Turtle **Join Zoom Webinar**

This satellite event will provide a tutorial overview of The Experiential Learning Lab (TELLab), a web-based system that allows students to create and run their own psychology experiments.

An introduction to TELLab 2.0 - A new-and-improved version of The Experiential Learning LABoratory, a web-based platform for educators

Monday, May 24, 8:00 - 9:00 pm EDT, Sea Turtle **Join Zoom Webinar**

Wednesday, May 26, 2:30 - 3:30 pm EDT, Sea Turtle **Join Zoom Webinar**

This satellite event will provide a tutorial overview of the new-and-improved version of The Experiential Learning Lab (TELLab2), a web-based system that allows students to create and run their own psychology experiments.

Canadian Vision Science Social

Friday, May 21, 8:00 - 10:00 pm EDT, Sawgrass **Join Zoom Webinar**

This social event is open to any VSS member who is, knows, or would like to meet a Canadian Vision Scientist! Hosted by Vision: Science to Applications (VISTA)

Measuring and Maximizing Eye Tracking Data Quality with EyeLinks

Saturday, May 22, 9:15 - 10:15 am EDT, Palm **Join Zoom Webinar**

Monday, May 24, 3:00 - 4:00 pm EDT, Sea Turtle **Join Zoom Webinar**

SR Research staff will discuss the key determinants of eye tracking data quality, and how critical metrics such as accuracy and precision can be derived from EyeLink data.

Mentoring Envisioned

Friday, May 21, 2:00 - 3:30 pm EDT, Sea Turtle

The Mentoring Envisioned project is being developed by the members of FoVea, Visibility, and SPARK, to facilitate networking and mentoring opportunities for all members of the VSS community.

New Tools for Conducting Eye Tracking Research

Saturday, May 22, 12:00 - 12:30 pm EDT, Palm **Join Zoom Webinar**

Monday, May 24, 9:00 - 9:30 am EDT, Sea Turtle **Join Zoom Webinar**

During this event, we'll discuss how Eyeware has overcome the challenges of intrusive headgear and expensive sensors with GazeSense.

Performing Eye Tracking Studies in VR

Tuesday, May 25, 9:15 - 10:15 am EDT, Sea Turtle **Join Zoom Webinar**

Tuesday, May 25, 5:15 - 6:15 pm EDT, Palm **Join Zoom Webinar**

Learn how to set up and perform eye tracking studies in VR using Python and a GUI based configurator. We will explain drag and drop methods for adding 360 videos and 3D models and demonstrate analytics methods with associated templates.

phiVIS: Philosophy of Vision Science Workshop

Sunday, May 23, 3:30 - 5:30 pm EDT, Sea Turtle **Join Zoom Webinar**

The phiVIS workshop is a forum for promoting and expanding interdisciplinary dialogue between vision scientists and philosophers.

Reunion: Visual Neuroscience From Spikes to Awareness

Monday, May 24, 8:45 - 10:45 am EDT, Palm **Join Zoom Webinar**

Tuesday, May 25, 2:30 - 4:30 pm EDT, Palm **Join Zoom Webinar**

The aim of this event is to catch up with all alumni of the European Summer School, Visual Neuroscience From Spikes to Awareness. To reënliven good memories of the Rauischholzhausen Castle.

Run MATLAB/Psychtoolbox Experiments Online with Pack & Go

Friday, May 21, 4:00 - 5:00 pm EDT, Palm **Join Zoom Webinar**

Sunday, May 23, 8:00 - 9:00 am EDT, Sea Turtle **Join Zoom Webinar**

The satellite's objective is to demonstrate the project's current state in a live demo and obtain early feedback from the community.

Teaching Vision

Monday, May 24, 4:15 - 6:15 pm EDT, Palm

Wednesday, May 26, 8:30 - 10:30 am EDT, Sea Turtle

In this Satellite Event we will provide a forum for instructors teaching vision-related courses to exchange ideas, best practices, and materials.

Virtual VPixx Hardware with the LabMaestro Simulator

Tuesday, May 25, 12:00 - 1:00 pm EDT, Sea Turtle **Join Zoom Webinar**

Want to test code remotely? Don't have access to VPixx hardware? The LabMaestro Hardware Simulator provides virtual I/O with little to no changes to experiment code. In this satellite we will cover basic synchronization principles and give some demonstrations.

Visibility: A Gathering of LGBTQ+ Vision Scientists and Friends

Monday, May 24, 11:00 am - 12:00 pm EDT, Sawgrass **Join Zoom Webinar**

We will form a network of support and discuss continuing challenges for queer scientists and for gay rights generally.

Satellite Events >

An introduction to TELLab – The Experiential Learning LABoratory, a web-based platform for educators

Saturday, May 22, 8:00 - 9:00 am EDT, Sea Turtle Join Zoom Webinar

Sunday, May 23, 6:00 - 7:00 pm EDT, Sea Turtle Join Zoom Webinar

Organizers: Jeff Mulligan, Independent contractor to UC Berkeley; Jeremy Wilmer, Wellesley College
Speakers: Ken Nakayama, Jeremy Wilmer, Justin Junge, Jeff Mulligan, Sarah Kerns

This satellite event will provide a tutorial overview of The Experiential Learning Lab (TELLab), a web-based system that allows students to create and run their own psychology experiments, either by copying and modifying one of the many existing experiments, or creating a new one entirely from scratch. The TELLab project was begun a number of years ago by Ken Nakayama and others at Harvard University, and continues today under Ken's leadership from his new position as adjunct professor at UC Berkeley. To date, TELLab has been used by around 20 instructors and 5000 students.

After a short introduction, TELLab gurus will demonstrate the process of creating and running an experiment, exporting the data and analyzing the results. Complete details can be found on TELLab's satellite information website **http://vss.tellab.org**. Potential attendees are encouraged to visit the site at **http://lab.tellab.org** beforehand to create their own account and explore the system on their own.

Hope to see you there. Happy experimenting!

Satellite Events >

An introduction to TELLab 2.0 – A new-and-improved version of The Experiential Learning LABoratory, a web-based platform for educators

Monday, May 24, 8:00 - 9:00 pm EDT, Sea Turtle **Join Zoom Webinar**

Wednesday, May 26, 2:30 - 3:30 pm EDT, Sea Turtle **Join Zoom Webinar**

Organizers: Jeff Mulligan, Independent contractor to UC Berkeley; Jeremy Wilmer, Wellesley College
Speakers: Ken Nakayama, Jeremy Wilmer, Justin Junge, Jeff Mulligan, Sarah Kerns

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After a short introduction, TELLab2 gurus will provide a live demonstration of some of the new capabilities. Complete details can be found on TELLab's satellite information website: **http://vss.tellab.org**. Potential attendees are welcome to visit the beta version of the site at **http://lab2.tellab.org**, with the caveat that the site is still in flux and not all of the advertised features are fully-functional as of this writing.

Hope to see you there. Happy experimenting!

Canadian Vision Science Social

Hosted by Vision: Science to Applications (VISTA)

Friday, May 21, 8:00 - 10:00 pm EDT, Sawgrass Join Zoom Webinar

Organizers: Caitlin Mullin, VISTA; Doug Crawford, York University
Speakers: Caitlin Mullin, VISTA; Doug Crawford, York University

This social event is open to any VSS member who is, knows, or would like to meet a Canadian Vision Scientist! Join us for casual discussions with students and faculty from several Canadian Institutes or to just satisfy your curiosity as to why we in the North are so polite and good natured, Eh? So grab your toques and your double-double and come connect with your favourite Canucks. This year long lock down is sure to make for some great hockey hair!

VISTA
VISION: SCIENCE TO APPLICATIONS
YORK UNIVERSITY

Measuring and Maximizing Eye Tracking Data Quality with EyeLinks

Saturday, May 22, 9:15 - 10:15 am EDT, Palm Join Zoom Webinar

Monday, May 24, 3:00 - 4:00 pm EDT, Sea Turtle Join Zoom Webinar

Organizer: Dr. Sam Hutton, SR Research Ltd
Speaker: Dr. Sam Hutton, SR Research Ltd

Understanding the key determinants of eye tracking data quality is critical for researchers who want to maximize their ability to detect significant effects in gaze metrics and generate and report high quality, replicable data. However, the topic is something of a terminological minefield, with concepts such as "noise" and "resolution" being used to mean different things by different researchers and manufacturers. In this Satellite Event, SR Research staff will discuss the key determinants of eye tracking data quality, and provide clear instructions for how critical data quality metrics such as accuracy and precision can be derived from EyeLink data. The workshop will also describe a range of tips and tricks that attendees can use to ensure they maximize data quality in their own EyeLink systems – from optimizing camera and participant set-up, to choosing the most appropriate calibration model. The overall aim of the event is to provide EyeLink users with the tools they need to measure and report eye tracking data quality, and to help them ensure that they are using their equipment optimally.

The following SR Research Webinar contains some useful background information: **How EyeLinks Work**.

For a list of other webinars and many other useful learning resources, please visit the **SR Research Support Forum** or the **Learning Resources** page on our website.

Mentoring Envisioned

Friday, May 21, 2:00 - 3:30 pm EDT, Sea Turtle **Join Zoom Webinar**

Organizers: Charisse Pickron, University of Minnesota; Alejandro Lleras, University of Illinois at Urbana-Champaign

The Mentoring Envisioned project is being developed by the members of FoVea, Visibility, and SPARK, to facilitate networking and mentoring opportunities for all members of the VSS community. The first half of the event will feature a panel discussion on mentoring (sponsored by FoVea) and the second half will include small group discussions of our newly launched Mentoring Envisioned SLACK channel, which will be open to all VSS members who are interested in building community and further developing connections both through affinity groups and through scientific interests. We hope the SLACK channel and mentoring event will foster new connections that will help participants, especially those new to VSS, navigate the meeting, network, and will provide strong social support for members of underrepresented groups in the society.

New Tools for Conducting Eye Tracking Research

Saturday, May 22, 12:00 - 12:30 pm EDT, Palm **Join Zoom Webinar**

Monday, May 24, 9:00 - 9:30 am EDT, Sea Turtle **Join Zoom Webinar**

Organizer: Chase Anderson
Speaker: Chase Anderson, Eyeware

Until recently, eye tracking research has been limited due to intrusive headgear or expensive sensors. This has restricted the ability of vision researchers to conduct studies at scale and within their budgets.

During this event, we'll discuss how Eyeware has overcome these challenges with GazeSense. This software uses consumer-grade 3D cameras to offer robust eye tracking data which can be exposed live via an API or in CSV format for later analysis. By using depth & RGB information, Gazesense can maintain reliable tracking better than traditional 2D trackers over extended periods of time.

We will also be introducing Beam, which enables an iPhone to be used as an eye tracking device. Beam takes advantage of the True Depth, user-facing cameras on any iPhone with Face ID. This new development allows vision researchers to run eye tracking experiments remotely, at scale, and provides access to the data.

To learn more about our mission, visit **Eyeware.tech** or contact us at **contact@eyeware.tech**.

We hope to see you at the satellite event!

Performing Eye Tracking Studies in VR

Tuesday, May 25, 9:15 - 10:15 am EDT, Sea Turtle Join Zoom Webinar

Tuesday, May 25, 5:15 - 6:15 pm EDT, Palm Join Zoom Webinar

Organizers: Belle Lin, WorldViz VR; Matthias Pusch, WorldViz VR
Speakers: Sado Rabaudi, Dan Tinkham, Matthias Pusch, Andrew Beall

WorldViz VR will teach participants how to set up and perform **eye tracking studies** in VR using Python and a GUI based configurator. We will explain drag and drop methods for adding 360 videos and 3D models, and demonstrate analytics methods with associated templates. At the end of this session participants will know how to insert their own 3D geometry or 360 video in VR scenes, generate 3D visualizations of the scene and gaze path, extract gaze intersects, view an interactive session replay, save out raw data, and modify the template using their own target objects and parameters.

The presentation and teaching will be provided as a remote meeting with screen-sharing. A live camera view will allow participants to observe the eye tracker setup and operation for several leading eye tracked VR headsets.

phiVIS: Philosophy of Vision Science Workshop

Sunday, May 23, 3:30 - 5:30 pm EDT, Sea Turtle Join Zoom Webinar

Organizers: Kevin Lande, York University; Chaz Firestone, Johns Hopkins University
Speakers: Ned Block, Silver Professor of Philosophy, Psychology and Neural Science, NYU; Jessie Munton, Lecturer in Philosophy, University of Cambridge; E.J. Green, Assistant Professor and Class of 1948 Career Development Chair in the Department of Linguistics and Philosophy, MIT; and a slate of invited vision scientists who will facilitate the discussion.

The past decade has seen a resurgence of interest in the intersection between vision science and the philosophy of perception. But opportunities for conversation between vision scientists and philosophers are still hard to come by. The phiVIS workshop is a forum for promoting and expanding this interdisciplinary dialogue. Philosophers of perception can capitalize on the experimental knowledge of working vision scientists, while vision scientists can take advantage of the opportunity to connect their research to long-standing philosophical questions. Short talks by philosophers of perception that engage with the latest research in vision science will be followed by discussion with a slate of vision scientists, on topics such as probabilistic representation in perception, perceptual constancy, amodal completion, multisensory perception, visual adaptation, and much else. This event is supported by York University's Vision: Science to Applications (VISTA) program and Centre for Vision Research, as well as the Johns Hopkins University Vision Sciences Group.

To register and to learn more about our speakers and our mission, visit **www.phivis.org**.

Reunion: Visual Neuroscience From Spikes to Awareness

Monday, May 24, 8:45 - 10:45 am EDT, Palm **Join Zoom Webinar**

Tuesday, May 25, 2:30 - 4:30 pm EDT, Palm **Join Zoom Webinar**

Organizers: Arash Akbarinia, Vivian Paulun, Guido Maiello, Kate Storrs, University of Giessen

Since 2004, **the European Summer School, Visual Neuroscience From Spikes to Awareness**, has taught many neuroscientists with a broad background. This event aims to reunite all the former alumni and trainees by presenting a number of exciting projects triggered at the Rauischholzhausen Castle. We also encourage the participation of prospective attendees who would like to learn about this Summer School, the various opportunities it offers, and the synergistic community it fosters. Alumni from all generations are invited to present their multidisciplinary, more-or-less scientific final projects. We hope there will be at least one contribution from every year of the summer school. This could be the final fun project or anything else you come up with, such as your favorite pictures from the summer school or a 'How It Started … How It's Going' of the attendees, be creative! The bottom line is to meet and catch up, so please do join us.

Run MATLAB/Psychtoolbox Experiments Online with Pack & Go

Friday, May 21, 4:00 - 5:00 pm EDT, Palm Join Zoom Webinar

Sunday, May 23, 8:00 - 9:00 am EDT, Sea Turtle Join Zoom Webinar

Organizers: Dr. Sophie Kenny, VPixx Technologies; Dr. Lindsey Fraser, VPixx Technologies
Moderator: Dr. Lindsey Fraser, Staff Scientist at VPixx Technologies
Speaker: Dr. Sophie Kenny, Staff Scientist at VPixx Technologies

Pack&Go is a remote experiment testing and data collection solution under development by VPixx Technologies. Pack&Go runs MATLAB/Psychtoolbox experiments developed by the vision and psychology research communities. The Pack&Go solution provides a high-performance computer architecture for executing Psychtoolbox code remotely. A vetted participant equipped with the correct links and credentials can access the experiment online and stream it to their browser on demand. The participant's technological requirements are relatively low: the participant will not need to download files to their device or meet specific hardware requirements aside from having a stable internet connection. Pack&Go records data files generated during the execution of the scripts programmed by the researcher, including formats such as .csv and .mat. The data files are stored on a secure server alongside anonymized participant information and information about the network's quality during the data collection session. When one or more participants have completed the online study, the experiment manager can download the data locally and analyze it, much in the same way as if the researcher had run the experiment on a local computer.

VPixx Technologies has worked since 2001 developing innovative hardware and software solutions to meet the needs of vision scientists and the extended research community. Pack&Go's development emerged from our long tradition of developing products based on continuous discussions with our customers and in conjunction with early-adopting labs willing to serve as guides for our development. Work on Pack&Go began in 2020 in collaboration with Dr. Caroline Blais and Dr. Daniel Fiset from the University of Quebec in Outaouais (UQO).

With Pack&Go, VPixx Technologies will enable researchers who use Psychtoolbox to retain the ability to design their complex experiments and stimuli and run them online, maintaining similarity with the xperiments they usually run in their laboratories).

The satellite session's objective is to demonstrate the project's current state in a live demo and obtain early feedback from the community.

We hope to see you at the satellite session!

Teaching Vision

Monday, May 24, 4:15 - 6:15 pm EDT, Palm **Join Zoom Webinar**

Wednesday, May 26, 8:30 - 10:30 am EDT, Sea Turtle **Join Zoom Webinar**

Organizer: Dirk Bernhardt-Walther, University of Toronto
Speakers: Jessica Witt, Colorado State University; Benjamin Balas, North Dakota State University; Michelle Greene, Bates College; Michael Cohen, Amherst College; Dirk Bernhardt-Walther, University of Toronto

The Covid-19 pandemic has catapulted instructors at universities and colleges into a new reality of online teaching. They had to rapidly adapt and innovate to adjust their proven classroom-based courses to the new reality of physically distant learning, with challenges to material delivery, student engagement, and student assessment. In this Satellite Event we will provide a forum for instructors teaching vision-related courses to exchange ideas, best practices, and materials. We will offer advice by experienced instructors on practical demonstrations that can be performed by students at home, student engagement in an online setting, open pedagogies in the online/hybrid realm, as well as incorporating online laboratory work in teaching vision-related courses. We will discuss ideas for bridging the gap between demonstrations and structured observations and the use of quantitative models for problem-solving in vision science courses. We invite the VSS community to participate in an open panel discussion to share their own experiences with teaching during the pandemic.

Jessica Witt

Colorado State University

Teaching a Sensation & Perception Lab On-Line

Benjamin Balas

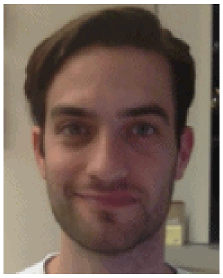
North Dakota State University

Vision science on paper: Analog demos to support problem-solving in Sensation & Perception

Michelle Greene

Bates College

Disposing with the disposable assignment: the power of open pedagogies for transformational learning



Michael Cohen

Amherst College

Strategies for assessing student learning

Dirk Bernhardt-Walther

University of Toronto

Forging an active student community in a large, asynchronous course

Virtual VPixx Hardware with the LabMaestro Simulator

Tuesday, May 25, 12:00 - 1:00 pm EDT, Sea Turtle Join Zoom Webinar

Organizers: Dr. Lindsey Fraser, VPixx Technologies; Dr. Sophie Kenny, VPixx Technologies
Speaker: Dr. Lindsey Fraser, VPixx Technologies

Over the past year, VPixx Technologies has developed the LabMaestro Simulator, a software tool that simulates VPixx's data acquisition hardware. The Simulator can record button presses from a virtual button box, simulate incoming triggers and analog signals to the virtual data acquisition system, and mimic timestamps for a virtual display. The LabMaestro Simulator allows researchers to develop and test experimental protocols without a connection to in-demand hardware or limited-access research sites, such as MRI suites. Little to no modification of code is required to switch between virtual and physical VPixx devices.

The goal of this satellite is to introduce the LabMaestro Simulator and provide an overview of its functionality. We will start with a review of the register-based architecture shared by all of our hardware, and the benefits this architecture offers for signal timing and synchronization. Principles such as writing to hardware registers, as well as locking triggers and data acquisition to visual events, will be discussed. We will show how the simulator replicates this architecture via a virtual server, and highlight the differences between the behaviour of virtual and physical devices, where such differences exist.

The satellite will end with a demonstration of some of the utilities available through our different licensing options. VPixx staff scientists will be available for questions about the Simulator at the end of the satellite, and throughout the remainder of the conference.

We look forward to seeing you there!

Visibility: A Gathering of LGBTQ+ Vision Scientists and Friends

Monday, May 24, 11:00 am - 12:00 pm EDT, Sawgrass Join Zoom Webinar

Organizers: Alex White, Barnard College; Michael Grubb, Trinity College

LGBTQ students are disproportionately likely to drop out of science early. Potential causes include the lack of visible role models and the absence of a strong community. This virtual gathering is one small step towards filling that gap. We will form a network of support and discuss continuing challenges for queer scientists and for gay rights generally (e.g., LGBT people are not protected against employment discrimination in the majority of the United States, an issue currently before the US Congress). This year we will have a special guest speaker who is very active in promoting the interests of LGBTQ+ scientists nationally. All are welcome.

Sponsors

The Vision Sciences Society thanks the following sponsors for their support of our 2021 meeting.

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worldviz VR where virtual becomes reality

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Elsevier/*Vision Research*

Elsevier is proud to sponsor the 2021 Young Investigator Award and the 2021 Elsevier/Vision Research Travel Awards.

Elsevier is a global information analytics business that helps institutions and professionals advance healthcare, open science and improve performance for the benefit of humanity.

We help researchers make new discoveries, collaborate with their colleagues, and give them the knowledge they need to find funding. We help governments and universities evaluate and improve their research strategies. We help doctors save lives, providing insight for physicians to find the right clinical answers, and we support nurses and other healthcare professionals throughout their careers. Our goal is to expand the boundaries of knowledge for the benefit of humanity.

VPixx Technologies

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VPixx is the proud sponsor of this year's Keynote Lecture by Suzana Herculano-Houzel.

VPixx Technologies welcomes the vision science community to V-VSS 2021. This year VPixx celebrates our 20th anniversary, and we are marking this special occasion with the launch of two new tools for your research: the LabMaestro Pack & Go Remote Testing Tool and the LabMaestro Hardware Simulator.

Over the past year, the need for remote data collection platforms has become clear. The VPixx team has created LabMaestro Pack & Go, a tool for remote data collection for MATLAB/Psychtoolbox-based experiment protocols. With Pack & Go researchers can deploy MATLAB/Psychtoolbox experiments to remote participants on a local or global scale, while monitoring communication performance to ensure data quality. This tool allows researchers to test participants using the subject's own personal computer, with no MATLAB/Psychtoolbox installation required. Consult the VSS Satellite Events if you would like to learn more, or to participate in your first Psychtoolbox Pack & Go experiment!

VPixx Technologies is known for our innovative hardware for vision research. The PROPixx DLP LED video projector, supporting refresh rates up to 1440Hz, has become a standard for neuroimaging, neurophysiology, and behavioral vision research applications. The TRACKPixx3 2kHz binocular eye tracker and the DATAPixx I/O hub offer microsecond-precise data acquisition synchronized to stimulus presentation. This year we launch the LabMaestro Hardware Simulator, a software tool that simulates VPixx hardware, allowing researchers to develop and test experiment protocols while the physical instruments are unavailable or in use. Consult the VSS Satellite Events if you would like to learn more!

Peter April, Jean-Francois Hamelin, and the entire VPixx Team wish you well.

Sponsors > Gold Sponsor

Vision: Science to Applications (VISTA)

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VISTA is the proud sponsor of this year's Just-In-Time Poster Session A and Session B.

Vision: Science to Applications (VISTA) is a collaborative program funded by the Canada First Research Excellence Fund (CFREF). VISTA's central 'vision' is to create a novel transdisciplinary program that expands and integrates York University's unique strengths in biological and computational vision and translates this research into real-world applications. Our interdisciplinary approach, spanning visual neuroscience to computer vision and beyond will create impact through strategic collaboration with our partners from around the globe. VISTA also provides important graduate, post-doctoral, and researcher funding **opportunities** to enable cutting-edge research, and will create knowledge and technologies that will help people live healthier, safer, and more productive lives. You can learn more about VISTA's highlights and accomplishments over the past 3.5 years on this soft copy version of our **Impact Report**.

Sponsors > Gold Sponsor

Facebook Reality Labs

Facebook Reality Labs is the proud sponsor of the 2021 Awards Session.

At **Facebook Reality Labs**, we bring together the brightest cross-disciplinary minds in one place to deliver our mission: build tools that help people feel connected, anytime, anywhere. Developers, researchers, engineers and designers all working together to help build a more expansive – and more inclusive – future for all of us.

Through the collaboration with Dr. Rucci's Lab at The University of Rochester we supported these three VSS posters:

- High-Resolution Eye-Tracking during Natural Real-World Interaction by Kapisthalam et al.
- Post-Saccadic Dynamics of Visual Sensitivity Across the Visual Field by Li et al.
- A Model of the Post-saccadic Dynamics of Visual Sensitivity by Yang et al.

Rogue Research Inc.

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Rogue Research has been your partner in neuroscience research for over 20 years. As developers of the Brainsight® family of neuronavigation systems for non-invasive brain stimulation, we have helped make transcranial magnetic stimulation more accurate and more reproducible while keeping it simple and effective. 20 years and 600 laboratories later, Brainsight® continues to evolve to meet the needs in non-invasive brain stimulation and has expanded into functional brain imaging. Brainsight NIRS combines the power of neuronavigation to ensure accurate placement of NIRS optodes with our NIRS hardware that incorporates low-profile, TMS, MRI and MEG compatible.

Rogue Research has expanded beyond navigation to develop our own, next-generation, TMS device: Elevate™ TMS. Elevate™ TMS offers control over the pulse shape to ensure more reproducible excitatory or inhibitory effects on the targeted network. While Brainsight® ensures accurate targeting and Elevate™ TMS ensures reliable circuit interaction, Rogue Research is actively developing a robotic positioner to ensure that the plan is accurately and efficiently carried out. The unique design will ensure reachability and simplicity.

Rogue Research also offers our Brainsight® Vet line of neurosurgical navigation tools including our microsurgical robot. We also offer custom and MRI compatible implants, a line of MRI coils and testing chairs.

SR Research Ltd.

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SR Research produces the EyeLink family of high-speed eye trackers and has been enabling scientists to perform cutting-edge research since the early 1990s. EyeLink systems are renowned for their outstanding technical specifications, temporal precision, and superb accuracy. The EyeLink 1000 Plus has the world's lowest spatial noise and can be used in the laboratory and in EEG/MEG/MRI environments. The EyeLink Portable Duo offers the same high levels of data quality in a small, portable package. SR Research also provides sophisticated experiment delivery and analysis software, and a truly legendary support service.

Qualcomm

Qualcomm is the world's leading wireless technology innovator and the driving force behind the development, launch, and expansion of 5G. When we connected the phone to the internet, the mobile revolution was born. Today, our foundational technologies enable the mobile ecosystem and are found in every 3G, 4G and 5G smartphone. We bring the benefits of mobile to new industries, including automotive, the internet of things, and computing, and are leading the way to a world where everything and everyone can communicate and interact seamlessly.

WorldViz VR

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For 20 years, **WorldViz VR** has helped over 1500 universities, businesses and government organizations to conduct **leading edge research** with Virtual Reality.

Over the years, WorldViz VR has developed **Vizard**, a python-based platform that enables users to rapidly build 3D virtual reality applications that solve real world business and research challenges.

At VSS 2021, WorldViz will present for the first time a fully GUI based tool that allows users to collect, review and **analyze eye tracking data** with support for all the major PC based VR eye tracking devices including the new StarVR One, Vive Pro Eye, Pupil Labs and Tobii VR. It will allow drag and drop adding of videos and 3D models, and many of the most used analytics methods are included into the provided templates.

Build a scene, run your experiment and review in minutes. Fully expandable and modifiable by using the GUI configurator or python code.

The WorldViz components allow integration of highly targeted **VR labs**, and we are happy to help customers configure their own labs, tailored to their specific needs.

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Eyeware

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Eyeware is a Swiss computer vision company developing eye tracking software for consumer-grade, depth sensing cameras. Our innovative 3D eye tracking enables real-world interactions, capturing user attention, intention, and interest. Eyeware`s technology can be easily adapted and integrated into a large variety of applications such as academic research, robotics, human-machine interaction, etc. Academic researchers can collect robust, accurate, and efficient attention data via our Python API or CSV export to understand how participants observe and respond to changes in their environment.

See an **overview video of the GazeSense App here** or **information about our SDK**. More information can be found on our **website**.

Brain Vision LLC

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Brain Vision is the leading team for EEG in Vision Science. We offer full integration of EEG with many leading eye-tracking and video systems we also provide flexible and robust solutions for both stationary and mobile EEG. All of our systems are available with a variety of electrode types such as saline-sponge nets, active gel, passive, and dry electrodes, which are easily expandable with bio-sensors like GSR, ECG, Respiration, and EMG. Our team is specialized in using EEG with other modalities such as fMRI, fNIRS, MEG, TMS, and tDCS/HDtDCS.

If you want to know how EEG and Vision Science improve each other, please feel free to contact us:

- Phone: **+1.877.EEG 4 MRI**
- Email: **info@brainvision.com**
- **Book a meeting or virtual demo** at a time convenient to you!

Let us help you push the edge of what research is possible!

Join our Applied Perception Science Team

Our team is tackling the scientific challenges that define cutting-edge augmented & virtual reality, addressing heretofore unanswered questions in vision science, perceptual metrics, displays & optics research.

Our Hiring:

- Currently Hiring for Research Scientist
- 2021/2022 PhD Research Intern Hiring Kicks Off ~ Oct 2021

Want to learn More?
Contact Anya Smith at nakrokhina@fb.com

ABOUT VISTA

VISTA is a collaborative research program funded by the Canada First Research Excellence Fund (CFREF). VISTA builds on York University's world-leading interdisciplinary expertise in biological and computer vision with over 80 academic, public, and for-profit partners.

HIGHLIGHTS

MISSION

Our mission is to advance vision science through computational and biological research perspectives and to produce applications that generate positive economic, societal, health and technological impacts for Canada and the world.

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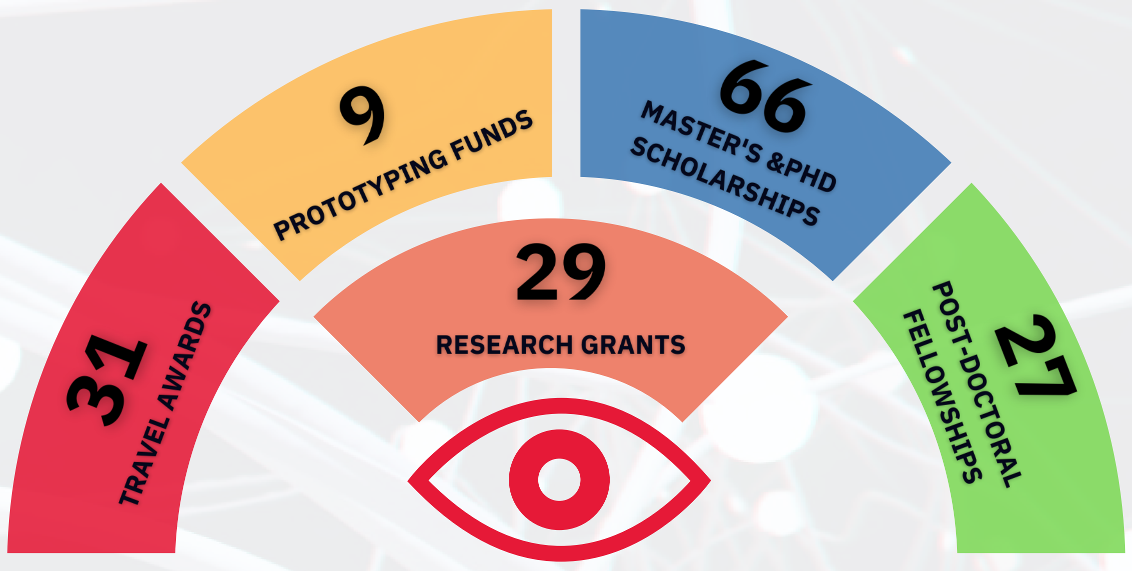

BECOME A VISTA AFFILIATE/PARTNER

Program benefits:

- Become a member of an interdisciplinary research community across the research areas of health, science, engineering, humanities, & arts
- Work with over 80 industry partners offering opportunities for research collaboration and product development
- Join an international network pushing the boundaries of vision research in North America, Europe, and Asia
- Collaborate on VISTA-funded research projects
- Participate in VISTA-funded events
- Travel Awards to support expenses for visiting scholars, students, and fellows to/from current VISTA partners

BECOME A VISTA TRAINEE

Master's Scholarships

- 2 year funding ($10,000/year), in addition to standard York University funding
- Supervisor must be a VISTA Core member

PhD Scholarships

- 4 year funding ($10,000/year), in addition to standard York University funding
- Supervisor must be a VISTA Core member

Postdoctoral Fellows

- 2 year funding ($55,000/year)
- Yearly Research and Networking allowances

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