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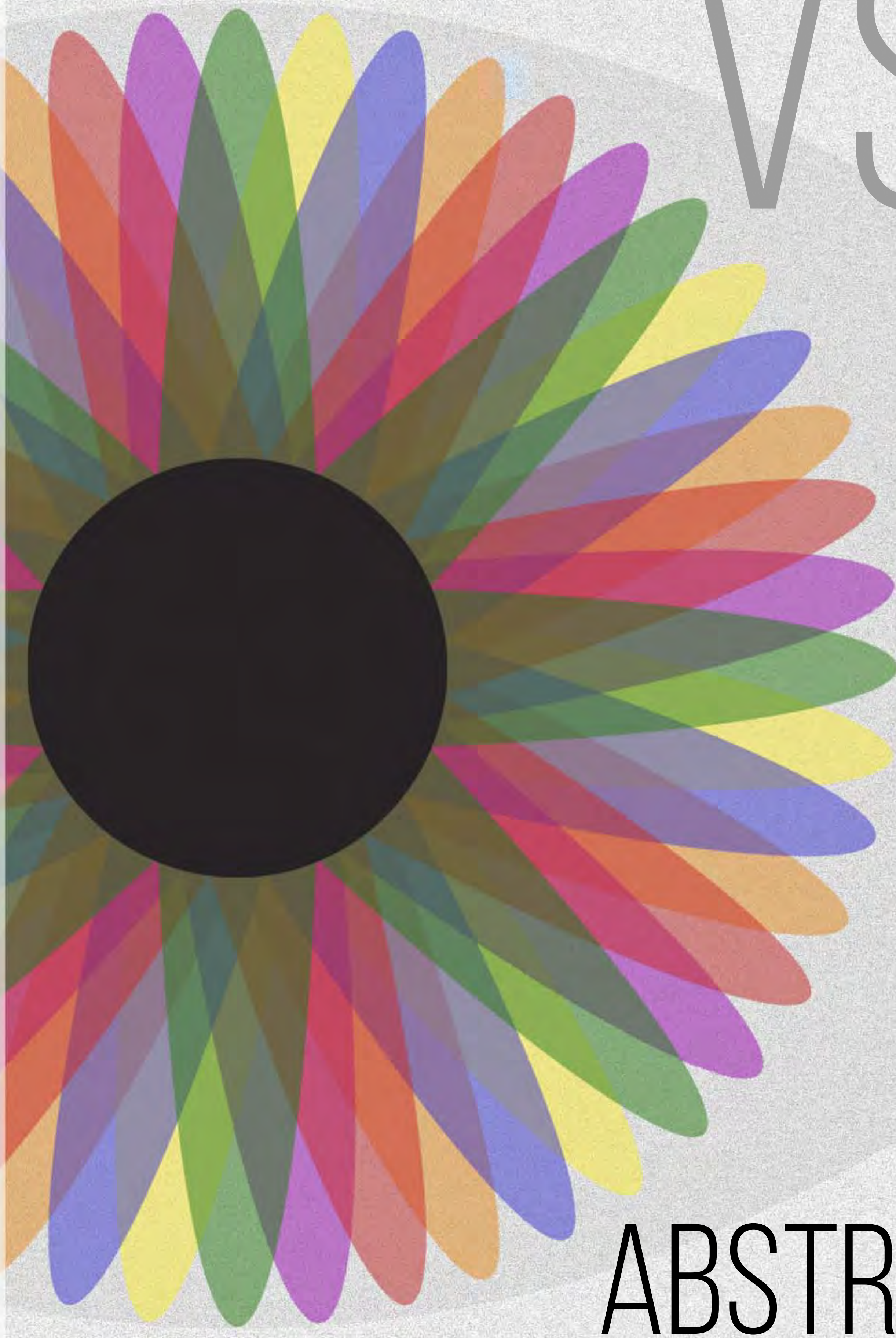

ABSTRACTS

VISION SCIENCES SOCIETY

17TH ANNUAL MEETING, MAY 19-24, 2017

TRADEWINDS ISLAND RESORTS, ST. PETE BEACH, FLORIDA

ABSTRACTS

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SESSIONS OVERVIEW

Abstract Numbering System

Each abstract is assigned a unique 4 or 6 digit number based on when and where it is to be presented. The format of the abstract numbering is DT.RN (where D is the Day, T is the Time, R is the Room and N is the presentation Number).

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2 Saturday	1 Early AM talk session	1 Talk Room 1	1, 2, 3... For talks
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4 Monday	3 AM poster session	3 Banyan Breezeway	
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MEMBER-INITIATED SYMPOSIA

SCHEDULE OVERVIEW

FRIDAY, MAY 19, 2017, 12:00 - 2:00 PM

S1 - A scene is more than the sum of its objects: The mechanisms of object-object and object-scene integration Talk Room 1

S2 - The Brain Correlates of Perception and Action: from Neural Activity to Behavior Pavilion

FRIDAY, MAY 19, 2017, 2:30 - 4:30 PM

S3 - How can you be so sure? Behavioral, computational, and neuroscientific perspectives on metacognition in perceptual decision-making Talk Room 1

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S5 - Cutting across the top-down-bottom-up dichotomy in attentional capture research Talk Room 1

S6 - Virtual Reality and Vision Science Pavilion

S1 - A SCENE IS MORE THAN THE SUM OF ITS OBJECTS: THE MECHANISMS OF OBJECT-OBJECT AND OBJECT-SCENE INTEGRATION

FRIDAY, MAY 19, 2017, 12:00 - 2:00 PM, TALK ROOM 1

Organizer(s): Liad Mudrik, Tel Aviv University and Melissa Võ, Goethe University Frankfurt

Presenters: Michelle Greene, Monica S. Castelhano, Melissa L.H. Võ, Nurit Gronau, Liad Mudrik

In the lab, vision researchers are typically trying to create "clean", controlled environments and stimulations in order to tease apart the different processes that are involved in seeing. Yet in real life, visual comprehension is never a sterile process: objects appear with other objects in cluttered, rich scenes, which have certain spatial and semantic properties. In recent years, more and more studies are focusing on object-object and object-scene relations as possible guiding principles of vision. The proposed symposium aims to present current findings in this continuously developing field, while specifically focusing on two key questions that have attracted substantial scientific interest in recent years; how do scene-object and object-object relations influence object processing, and what are the necessary conditions for deciphering these relations. Greene, Castelhano and Võ will each tackle the first question in different ways, using information theoretic measures, visual search findings, eye movement, and EEG measures. The second question will be discussed with respect to attention and consciousness: Võ's findings suggest automatic processing of object-scene relations, but do not rule out the need for attention. This view is corroborated and further stressed by Gronau's results. With respect to consciousness, Mudrik, however, will present behavioral and neural data suggesting that consciousness may not be an immediate condition for relations processing, but rather serve as a necessary enabling factor. Taken together, these talks should lay the ground for an integrative discussion of both complimentary and conflicting findings. Whether these are based on different theoretical assumptions, methodologies or experimental approaches, the core of the symposium will speak to how to best tackle the investigation of the complexity of real-world scene perception.

MEASURING THE EFFICIENCY OF CONTEXTUAL KNOWLEDGE

Speaker: Michelle Greene, Stanford University

The last few years have brought us both large-scale image databases and the ability to crowd-source human data collection, allowing us to measure contextual statistics in real world scenes (Greene, 2013). How much contextual information is there, and how efficiently do people use it? We created a visual analog to a guessing game suggested by Claude Shannon (1951) to measure the information scenes and objects share. In our game, 555 participants on Amazon's Mechanical Turk (AMT) viewed scenes in which a single object was covered by an opaque bounding box. Participants were instructed to guess about the identity of the hidden object until correct. Participants were paid per trial, and each trial terminated upon correctly guessing the object, so participants were incentivized to guess as efficiently as possible. Using information theoretic measures, we found that scene context can be encoded with less than 2 bits per object, a level of redundancy that is even greater than that of English text. To assess the information from scene category, we ran a second experiment in which the image was replaced by the scene category name. Participants still outperformed the entropy of the database, suggesting that the majority of contextual knowledge is carried by the category schema. Taken together, these results suggest that not only is there a great deal of information about objects coming from scene categories, but that this information is efficiently encoded by the human mind.

WHERE IN THE WORLD?: EXPLAINING SCENE CONTEXT EFFECTS DURING VISUAL SEARCH THROUGH OBJECT-SCENE SPATIAL ASSOCIATIONS

Speaker: Monica S. Castelhano, Queen's University

The spatial relationship between objects and scenes and its effects on visual search performance has been well-established. Here, we examine how object-scene spatial associations support scene context effects on eye movement guidance and search efficiency. We reframed two classic visual search paradigms (set size and sudden onset) according to the spatial association between the target object and scene. Using the recently proposed Surface Guidance Framework, we operationalize target-relevant and target-irrelevant regions. Scenes are divided into three regions (upper, mid, lower) that correspond with possible relevant surfaces (wall, countertop, floor). Target-relevant regions are defined according to the surface on which the target is likely to appear (e.g., painting, toaster, rug). In the first experiment, we explored how spatial associations affect search by manipulating search size in either target-relevant or target-irrelevant regions. We found that only set size increases in target-relevant regions adversely affected search performance. In the second experiment, we manipulated whether a suddenly-onsetting distractor object appeared in a target-relevant or target-irrelevant region. We found that fixations to the distractor were significantly more likely and search performance was negatively affected in the target-relevant condition. The Surface Guidance Framework allows for further exploration of how object-scene spatial associations can be used to quickly narrow processing to specific areas of the scene and largely ignore information in other areas. Viewing effects of scene context through the lens of target-relevancy allows us to develop new understanding of how the spatial associations between objects and scenes can affect performance.

WHAT DRIVES SEMANTIC PROCESSING OF OBJECTS IN SCENES?

Speaker: Melissa L.H. Võ, Goethe University Frankfurt

Objects hardly ever appear in isolation, but are usually embedded in a larger scene context. This context — determined e.g. by the co-occurrence of other objects or the semantics of the scene as a whole — has large impact on the processing of each and every object. Here I will present a series of eye tracking and EEG studies from our lab that 1) make use of the known

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time-course and neuronal signature of scene semantic processing to test whether seemingly meaningless textures of scenes are sufficient to modulate semantic object processing, and 2) raise the question of its automaticity. For instance, we have previously shown that semantically inconsistent objects trigger an N400 ERP response similar to the one known from language processing. Moreover, an additional but earlier N300 response signals perceptual processing difficulties that go in line with classic findings of impeded object identification from the 1980s. We have since used this neuronal signature to investigate scene context effects on object processing and recently found that a scene's mere summary statistics — visualized as seemingly meaningless textures — elicit a very similar N400 response. Further, we have shown that observers looking for target letters superimposed on scenes fixated task-irrelevant semantically inconsistent objects embedded in the scenes to a greater degree and without explicit memory for these objects. Manipulating the number of superimposed letters reduced this effect, but not entirely. As part of this symposium, we will discuss the implications of these findings for the question as to whether object-scene integration requires attention.

Vision at a glance: the necessity of attention to contextual integration processes

Speaker: Nurit Gronau, The Open University of Israel

Objects that are conceptually consistent with their environment are typically grasped more rapidly and efficiently than objects that are inconsistent with it. The extent to which such contextual integration processes depend on visual attention, however, is largely disputed. The present research examined the necessity of visual attention to object-object and object-scene contextual integration processes during a brief visual glimpse. Participants performed an object classification task on associated object pairs that were either positioned in expected relative locations (e.g., a desk-lamp on a desk) or in unexpected, contextually inconsistent relative locations (e.g., a desk-lamp under a desk). When both stimuli were relevant to task requirements, latencies to spatially consistent object pairs were significantly shorter than to spatially inconsistent pairs. These contextual effects disappeared, however, when spatial attention was drawn to one of the two object stimuli while its counterpart object was positioned outside the focus of attention and was irrelevant to task-demands. Subsequent research examined object-object and object-scene associations which are based on categorical relations, rather than on specific spatial and functional relations. Here too, processing of the semantic/categorical relations necessitated allocation of spatial attention, unless an unattended object was explicitly defined as a to-be-detected target. Collectively, our research suggests that associative and integrative contextual processes underlying scene understanding rely on the availability of spatial attentional resources. However, stimuli which comply with task-requirements (e.g., a cat/dog in an animal, but not in a vehicle detection task) may benefit from efficient processing even when appearing outside the main focus of visual attention.

Object-object and object-scene integration: the role of conscious processing

Speaker: Liad Mudrik, Tel Aviv University

On a typical day, we perform numerous integration processes; we repeatedly integrate objects with the scenes in which they appear, and decipher the relations between objects, resting both on their tendency to co-occur and on their semantic associations. Such integration seems effortless, almost automatic, yet computationally speaking it is highly complicated and challenging. This apparent contradiction evokes the question of consciousness' role in the process: is it automatic enough to obviate the need for conscious processing, or does its complexity necessitate the involvement of conscious experience? In this talk, I will present EEG, fMRI and behavioral experiments that tap into consciousness' role in processing object-scene integration and object-object integration. The former revisits subjects' ability to integrate the relations (congruency/incongruency) between an object and the scene in which it appears. The latter examines the processing of the relations between two objects, in an attempt to differentiate between associative relations (i.e., relations that rest on repeated co-occurrences of the two objects) vs. abstract ones (i.e., relations that are more conceptual, between two objects that do not tend to co-appear but are nevertheless related). I will claim that in both types of integration, consciousness may function as an enabling factor rather than an immediate necessary condition.

S2 - The Brain Correlates of Perception and Action: from neural activity to behavior

Friday, May 19, 2017, 12:00 - 2:00 pm, Pavilion

Organizer(s): Simona Monaco, Center for Mind/Brain Sciences, University of Trento & Annalisa Bosco, Department of Pharmacy and Biotech, University of Bologna

Presenters: J. Douglas Crawford, Patrizia Fattori, Simona Monaco, Annalisa Bosco, Jody C. Culham

In recent years neuroimaging and neurophysiology have enabled cognitive neuroscience to identify numerous brain areas that are involved in sensorimotor integration for action. This research has revealed cortical and subcortical brain structures that work in coordination to allow accurate hand and eye movements. The visual information about objects in the environment is integrated into the motor plan through a cascade of events known as visuo-motor integration. These mechanisms allow not only to extract relevant visual information for action, but also to continuously update this information throughout action plan and execution. As our brain evolved to act towards real objects in the natural environment, studying hand and eye movements in experimental situations that resemble the real world is critical for our understanding of the action system. This aspect has been relatively neglected in the cognitive sciences, mostly because of the challenges associated with the experimental setups and technologies. This symposium provides a comprehensive view of the neural mechanisms underlying sensory-motor integration for the production of eye and hand movements in situations that are common to real life. The range of topics covered by the speakers encompasses the visual as well as the motor and cognitive neurosciences, and therefore are relevant to junior and senior scientists specialized in any of these areas. We bring together researchers from macaque neurophysiology to human neuroimaging and behavior. The combination of works that use these cutting-edge techniques offers a unique insight into the effects that are detected at the neuronal level, extended to neural populations and translated into behavior. There will be five speakers. Doug Crawford will address the neuronal mechanisms underlying perceptual-motor integration during head-unrestrained gaze shifts in the frontal eye field and superior colliculus of macaques. Patrizia Fattori will describe how the activity of neurons in the dorsomedial visual stream of macaques is modulated by gaze and hand movement direction as well as properties of real objects. Jody Culham will illustrate the neural representation for visually guided actions and real objects in the human brain revealed by functional magnetic resonance imaging (fMRI). Simona Monaco will describe the neural mechanisms in the human brain underlying the influence of intended action on sensory processing and the involvement of the early visual cortex in action planning and execution. Annalisa Bosco will detail the behavioral aspects of the influence exerted by action on perception in human participants.

Visual-motor transformations at the Neuronal Level in the Gaze System

Speaker: J. Douglas Crawford, Centre for Vision Research, York University, Toronto, Ontario, Canada

Additional Authors: AmirSaman Sajad, Center for Integrative & Cognitive Neuroscience, Vanderbilt University, Nashville, TN and Morteza Sadeh, Centre for Vision Research, York University, Toronto, Ontario, Canada

The fundamental question in perceptual-motor integration is how, and at what level, do sensory signals become motor signals? Does this occur between brain areas, within brain areas, or even within individual neurons? Various training or cognitive paradigms have been combined with neurophysiology and/or neuroimaging to address this question, but the visuomotor transformations for ordinary gaze saccades remain elusive. To address these questions, we developed a method for fitting visual and motor response fields against various spatial models without any special training, based on trial-to-trial variations in behavior (DeSouza et al. 2011). More recently we used this to track visual-motor transformations through time. We find that superior colliculus and frontal eye field visual responses encode target direction, whereas their motor responses encode final gaze position relative to initial eye orientation (Sajad et al. 2015; Sadeh et al. 2016). This occurs both between neuron populations, but can also be observed within individual visuomotor cells. When a memory delay is imposed, a gradual transition of intermediate codes is observed (perhaps due to an imperfect memory loop), with a further 'leap' toward gaze motor coding in the final memory-motor transformation (Sajad et al. 2016). However, we found a similar spatiotemporal transition even within the brief burst of neural activity that accompanies a reactive, visually-evoked saccade. What these data suggest is that visuomotor transformations are a network phenomenon that is simultaneously observable at the level of individual neurons, and distributed across different neuronal populations and structures.

Neurons for eye and hand action in the monkey medial posterior parietal cortex

Speaker: Patrizia Fattori, University of Bologna

Additional Authors: Fattori Patrizia, Breveglieri Rossella, Galletti Claudio, Department of Pharmacy and Biotechnology, University of Bologna

In the last decades, several components of the visual control of eye and hand movements have been disentangled by studying single neurons in the brain of awake macaque monkeys. In this presentation, particular attention will be given to the influence of the direction of gaze upon the reaching activity of neurons of the dorsomedial visual stream. We recorded from the caudal part of the medial posterior parietal cortex, finding neurons sensitive to the direction and amplitude of arm reaching actions. The reaching activity of these neurons was influenced by the direction of gaze, some neurons preferring foveal reaching, others peripheral reaching. Manipulations of eye/target positions and of hand position showed that the reaching activity could be in eye-centered, head-centered, or a mixed frame of reference according to the considered neuron. We also found neurons modulated by the visual features of real objects and neurons modulated also by grasping movements, such as wrist orientation and grip formation. So it seems that the entire neural machinery for encoding eye and hand action is hosted in the dorsomedial visual stream. This machinery takes part in the sequence of visuomotor transformations required to encode many aspects of the reach-to-grasp actions.

The role of the early visual cortex in action

Speaker: Simona Monaco, Center for Mind/Brain Sciences, University of Trento

Additional Authors: Simona Monaco, Center for Mind/Brain Sciences, University of Trento; Doug Crawford, Centre for Vision Research, York University, Toronto, Ontario, Canada; Luca Turella, Center for Mind/Brain Sciences, University of Trento; Jody Culham, Brain and Mind Institution

Functional magnetic resonance imaging has recently allowed showing that intended action modulates the sensory processing of object orientation in areas of the action network in the human brain. In particular, intended actions can be decoded in the early visual cortex using multivoxel pattern analyses before the movements are initiated, regardless of whether the target object is visible or not. In addition, the early visual cortex is re-recruited during actions in the dark towards stimuli that have been previously seen. These results suggest three main points. First, the action-driven modulation of sensory processing is shown at the neural level in a network of areas that include the early visual cortex. Second, the role of the early visual cortex goes well beyond the processing of sensory information for perception and might be the target of reentrant feedback for sensory-motor integration. Third, the early visual cortex shows action-driven modulation during both action planning and execution, suggesting a continuous exchange of information with higher-order visual-motor areas for the production of a motor output.

The influence of action execution on object size perception

Speaker: Annalisa Bosco, Department of Pharmacy and Biotechnology, University of Bologna

Additional Authors: Annalisa Bosco, Department of Pharmacy and Biotechnology, University of Bologna; Patrizia Fattori, Department of Pharmacy and Biotechnology, University of Bologna

When performing an action, our perception is focused towards object visual properties that enable us to execute the action successfully. However, the motor system is also able to influence perception, but only few studies reported evidence for hand action-induced visual perception modifications. Here, we aimed to study for a feature-specific perceptual modulation before and after a reaching and grasping action. Two groups of subjects were instructed to either grasp or reach to different sized bars and, before and after the action, to perform a size perceptual task by manual and verbal report. Each group was tested in two experimental conditions: no prior knowledge of action type, where subjects did not know the successive type of movement, and prior knowledge of action type, where they were aware about the successive type of movement. In both manual and verbal perceptual size responses, we found that after a grasping movement the size perception was significantly modified. Additionally, this modification was enhanced when the subjects knew in advance the type of movement to execute in the subsequent phase of task. These data suggest that the knowledge of action type and the execution of the action shape the perception of object properties.

Neuroimaging reveals the human neural representations for visually guided grasping of real objects and pictures

Speaker: Jody C. Culham, Brain and Mind Institute, University of Western Ontario

Additional Authors: Jody C. Culham, University of Western Ontario; Sara Fabbri, Radboud University Nijmegen; Jacqueline C. Snow, University of Nevada, Reno; Erez Freud, Carnegie-Mellon University

Neuroimaging, particularly functional magnetic resonance imaging (fMRI), has revealed many human brain areas that are involved in the processing of visual information for the planning and guidance of actions. One area of particular interest is the anterior intraparietal sulcus (aIPS), which is thought to play a key role in processing information about object shape for the visual control of grasping. However, much fMRI research has relied on artificial stimuli, such as two-dimensional photos, and artificial actions, such as pantomimed grasping. Recent fMRI studies from our lab have used representational similarity analysis on the patterns of fMRI activation from brain areas such as aIPS to infer neural coding in participants performing real actions upon real objects. This research has revealed the visual features of the object (particularly elongation) and the type of grasp (including the number of digits and precision required) that are coded in aIPS and other regions. Moreover, this work has suggested that these neural representations are affected by the realness of the object, particularly during grasping. Taken together, these results highlight the value of using more ecological paradigms to study sensorimotor control.

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S3 - How can you be so sure? Behavioral, computational, and neuroscientific perspectives on metacognition in perceptual decision-making

Friday, May 19, 2017, 2:30 - 4:30 pm, Talk Room 1

Organizer(s): Megan Peters, University of California Los Angeles

Presenters: Megan Peters, Ariel Zylberberg, Michele Basso, Wei Ji Ma, Pascal Mamassian

Metacognition, or our ability to monitor the uncertainty of our thoughts, decisions, and perceptions, is of critical importance across many domains. Here we focus on metacognition in perceptual decisions -- the continuous inferences that we make about the most likely state of the world based on incoming sensory information. How does a police officer evaluate the fidelity of his perception that a perpetrator has drawn a weapon? How does a driver compute her certainty in whether a fleeting visual percept is a child or a soccer ball, impacting her decision to swerve? These kinds of questions are central to daily life, yet how such 'confidence' is computed in the brain remains unknown. In recent years, increasingly keen interest has been directed towards exploring such metacognitive mechanisms from computational (e.g., Rahnev et al., 2011, Nat Neuro; Peters & Lau, 2015, eLife), neuroimaging (e.g., Fleming et al., 2010, Science), brain stimulation (e.g., Fetsch et al., 2014, Neuron), and neuronal electrophysiology (e.g., Kiani & Shadlen, 2009, Science; Zylberberg et al., 2016, eLife) perspectives. Importantly, the computation of confidence is also of increasing interest to the broader range of researchers studying the computations underlying perceptual decision-making in general. Our central focus is on how confidence is computed in neuronal populations, with attention to (a) whether perceptual decisions and metacognitive judgments depend on the same or different computations, and (b) why confidence judgments sometimes fail to optimally track the accuracy of perceptual decisions. Key themes for this symposium will include neural correlates of confidence, behavioral consequences of evidence manipulation on confidence judgments, and computational characterizations of the relationship between perceptual decisions and our confidence in them. Our principal goal is to attract scientists studying or interested in confidence/uncertainty, sensory metacognition, and perceptual decision-making from both human and animal perspectives, spanning from the computational to the neurobiological level. We bring together speakers from across these disciplines, from animal electrophysiology and behavior through computational models of human uncertainty, to communicate their most recent and exciting findings. Given the recency of many of the findings discussed, our symposium will cover terrain largely untouched by the main program. We hope that the breadth of research programs represented in this symposium will encourage a diverse group of scientists to attend and actively participate in the discussion.

Transcranial magnetic stimulation to visual cortex induces suboptimal introspection

Speaker: Megan Peters, University of California Los Angeles

Additional Authors: Megan Peters, University of California Los Angeles; Jeremy Fesi, The Graduate Center of the City University of New York; Namema Amendi, The Graduate Center of the City University of New York; Jeffrey D. Knotts, University of California Los Angeles; Hakwan

In neurological cases of blindsight, patients with damage to primary visual cortex can discriminate objects but report no visual experience of them. This form of 'unconscious perception' provides a powerful opportunity to study perceptual awareness, but because the disorder is rare, many researchers have sought to induce the effect in neurologically intact observers. One promising approach is to apply transcranial magnetic stimulation (TMS) to visual cortex to induce blindsight (Boyer et al., 2005), but this method has been criticized for being susceptible to criterion bias confounds: perhaps TMS merely reduces internal visual signal strength, and observers are unwilling to report that they faintly saw a stimulus even if they can still discriminate it (Lloyd et al., 2013). Here we applied a rigorous response-bias free 2-interval forced-choice method for rating subjective experience in studies of unconscious perception (Peters and Lau, 2015) to address this concern. We used Bayesian ideal observer analysis to demonstrate that observers' introspective judgments about stimulus visibility are suboptimal even when the task does not require that they maintain a response criterion -- unlike in visual masking. Specifically, observers appear metacognitively blind to the noise introduced by TMS, in a way that is akin to neurological cases of blindsight. These findings are consistent with the hypothesis that metacognitive judgments require observers to develop an internal model of the statistical properties of their own signal processing architecture, and that introspective suboptimality arises when that internal model abruptly becomes invalid due to external manipulations.

The influence of evidence volatility on choice, reaction time and confidence in a perceptual decision

Speaker: Ariel Zylberberg, Columbia University

Additional Authors: Ariel Zylberberg, Columbia University; Christopher R. Fetsch, Columbia University; Michael N. Shadlen, Columbia University

Many decisions are thought to arise via the accumulation of noisy evidence to a threshold or bound. In perceptual decision-making, the bounded evidence accumulation framework explains the effect of stimulus strength, characterized by signal-to-noise ratio, on decision speed, accuracy and confidence. This framework also makes intriguing predictions about the behavioral influence of the noise itself. An increase in noise should lead to faster decisions, reduced accuracy and, paradoxically, higher confidence. To test these predictions, we introduce a novel sensory manipulation that mimics the addition of unbiased noise to motion-selective regions of visual cortex. We verified the effect of this manipulation with neuronal recordings from macaque areas MT/MST. For both humans and monkeys, increasing the noise induced faster decisions and greater confidence over a range of stimuli for which accuracy was minimally impaired. The magnitude of the effects was in agreement with predictions of a bounded evidence accumulation model.

A role for the superior colliculus in decision-making and confidence

Speaker: Michele Basso, University of California Los Angeles

Additional Authors: Michele Basso, University of California Los Angeles; Piercesare Grimaldi, University of California Los Angeles; Trinity Crapse, University of California Los Angeles

Evidence implicates the superior colliculus (SC) in attention and perceptual decision-making. In a simple target-selection task, we previously showed that discriminability between target and distractor neuronal activity in the SC correlated with decision accuracy, consistent with the hypothesis that SC encodes a decision variable. Here we extend these results to determine whether SC also correlates with decision criterion and confidence. Trained monkeys performed a simple perceptual decision task in two conditions to induce behavioral response bias (criterion shift): (1) the probability of two perceptual stimuli was equal, and (2) the probability of one perceptual stimulus was higher than the other. We observed consistent changes in behavioral response bias (shifts in decision criterion) that were directly correlated with SC neuronal activity. Furthermore, electrical stimulation of SC mimicked the effect of stimulus probability manipulations, demonstrating that SC correlates with and is causally involved in setting decision criteria. To assess confidence, monkeys were offered a 'safe bet' option on 50% of trials in a similar task. The 'safe bet' always yielded a small reward, encouraging monkeys to select the 'safe bet' when they were less confident rather

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than risk no reward for a wrong decision. Both monkeys showed metacognitive sensitivity: they chose the 'safe bet' more on more difficult trials. Single- and multi-neuron recordings from SC revealed two distinct neuronal populations: one that discharged more robustly for more confident trials, and one that did so for less confident trials. Together these finding show how SC encodes information about decisions and decisional confidence.

Testing the Bayesian confidence hypothesis

Speaker: Wei Ji Ma, New York University

Additional Authors: Wei Ji Ma, New York University; Will Adler, New York University; Ronald van den Berg, University of Uppsala

Asking subjects to rate their confidence is one of the oldest procedures in psychophysics. Remarkably, quantitative models of confidence ratings have been scarce. What could be called the "Bayesian confidence hypothesis" states that an observer's confidence rating distribution is completely determined by posterior probability. This hypothesis predicts specific quantitative relationships between performance and confidence. It also predicts that stimulus combinations that produce the same posterior will also produce the same confidence distribution. We tested these predictions in three contexts: a) perceptual categorization; b) visual working memory; c) the interpretation of scientific data.

Integration of visual confidence over time and across stimulus dimensions

Speaker: Pascal Mamassian, Ecole Normale Supérieure

Additional Authors: Pascal Mamassian, Ecole Normale Supérieure; Vincent de Gardelle, Université Paris 1; Alan Lee, Lingnan University

Visual confidence refers to our ability to estimate our own performance in a visual decision task. Several studies have highlighted the relatively high efficiency of this meta-perceptual ability, at least for simple visual discrimination tasks. Are observers equally good when visual confidence spans more than one stimulus dimension or more than a single decision? To address these issues, we used the method of confidence forced-choice judgments where participants are prompted to choose between two alternatives the stimulus for which they expect their performance to be better (Barthelmé & Mamassian, 2009, PLoS CB). In one experiment, we asked observers to make confidence choice judgments between two different tasks (an orientation-discrimination task and a spatial-frequency-discrimination task). We found that participants were equally good at making these across-dimensions confidence judgments as when choices were restricted to a single dimension, suggesting that visual confidence judgments share a common currency. In another experiment, we asked observers to make confidence-choice judgments between two ensembles of 2, 4, or 8 stimuli. We found that participants were increasingly good at making ensemble confidence judgments, suggesting that visual confidence judgments can accumulate information across several trials. Overall, these results help us better understand how visual confidence is computed and used over time and across stimulus dimensions.

S4 -The Role of Ensemble Statistics in the Visual Periphery

Friday, May 19, 2017, 2:30 - 4:30 pm, Pavilion

Organizer(s): Brian Odegaard, University of California-Los Angeles

Presenters: Michael Cohen, David Whitney, Ruth Rosenholtz, Tim Brady, Brian Odegaard

The past decades have seen the growth of a tremendous amount of research into the human visual system's capacity to encode "summary statistics" of items in the world. Studies have shown that the visual system possesses a remarkable ability to compute properties such as average size, position, motion direction, gaze direction, emotional expression, and liveliness, as well as variability in color and facial expression, documenting the phenomena across various domains and stimuli. One recent proposal in the literature has focused on the promise of ensemble statistics to provide an explanatory account of subjective experience in the visual periphery (Cohen, Dennett, & Kanwisher, Trends in Cognitive Sciences, 2016). In addition to this idea, others have suggested that summary statistics underlie performance in visual tasks in a broad manner. These hypotheses open up intriguing questions: how are ensemble statistics encoded outside the fovea, and to what extent does this capacity explain our experience of the majority of our visual field? In this proposed symposium, we aim to discuss recent empirical findings, theories, and methodological considerations in pursuit of answers to many questions in this growing area of research, including the following: (1) How does the ability to process summary statistics in the periphery compare to this ability at the center of the visual field? (2) What role (if any) does attention play in the ability to compute summary statistics in the periphery? (3) Which computational modeling frameworks provide compelling, explanatory accounts of this phenomenon? (4) Which summary statistics (e.g., mean, variance) are encoded in the periphery, and are there limitations on the precision/capacity of these estimates? By addressing questions such as those listed above, we hope that participants emerge from this symposium with a more thorough understanding of the role of ensemble statistics in the visual periphery, and how this phenomenon may account for subjective experience across the visual field. Our proposed group of speakers is shown below, and we hope that faculty, post-docs, and graduate students alike would find this symposium to be particularly informative, innovative, and impactful.

Ensemble statistics and the richness of perceptual experience

Speaker: Michael Cohen, MIT

While our subjective impression is of a detailed visual world, a wide variety of empirical results suggest that perception is actually rather limited. Findings from change blindness and inattentional blindness highlight how much of the huge amounts of the visual world regularly go unnoticed. Furthermore, direct estimates of the capacity of visual attention and working memory reveal that surprisingly few items can be processed and maintained at once. Why do we think we see so much when these empirical results suggests we see so little? One possible answer to this question resides in the representational power of visual ensembles and summary statistics. Under this view, those items that cannot be represented as individual objects or with great precision are nevertheless represented as part of a broader statistical summary. By representing much of the world as an ensemble, observers have perceptual access to different aspects of the entire field of view, not just a few select items. Thus, ensemble statistics play a critical role in our ability to account for and characterize the apparent richness of perceptual experience.

Ensemble representations as a basis for rich perceptual experiences

Speaker: David Whitney, University of California-Berkeley

Much of our rich visual experience comes in the form of ensemble representations, the perception of summary statistical information in groups of objects—such as the average size of items, the average emotional expression of faces in a crowd, or the average heading direction of point-light walkers. These ensemble percepts occur over space and time, are robust to outliers, and can occur in the visual periphery. Ensemble representations can even convey unique and emergent social information like the gaze of an audience, the animacy of a scene, or the panic in a crowd, information that is not necessarily available at the level of the individual crowd members. The visual system can make these high-level interpretations of social and emotional content with exposures as brief as 50 ms, thus revealing an extraordinarily efficient process for compressing what would otherwise be an overwhelming amount of information. Much of what is believed to count as rich social, emotional, and cognitive experience actually comes in the form of basic, compulsory, visual summary statistical processes.

Summary statistic encoding plus limits on decision complexity underlie the richness of visual perception as well as its quirky failures

Speaker: Ruth Rosenholtz, MIT

Visual perception is full of puzzles. Human observers effortlessly perform many visual tasks, and have the sense of a rich percept of the visual world. Yet when probed for details they are at a loss. How does one explain this combination of marvelous successes and puzzling failures? Numerous researchers have explained the failures in terms of severe limits on resources of attention and memory. But if so, how can one explain the successes? My lab has argued that many experimental results pointing to apparent attentional limits instead derived at least in part from losses in peripheral vision. Furthermore, we demonstrated that those losses could arise from peripheral vision encoding its inputs in terms of a rich set of local image statistics. This scheme is theoretically distinct from encoding ensemble statistics of a set of similar items. I propose that many of the remaining attention/memory limits can be unified in terms of a limit on decision complexity. This decision complexity is difficult to reason about, because the complexity of a given task depends upon the underlying encoding. A complex, general-purpose encoding likely evolved to make certain tasks easy at the expense of others. Recent advances in understanding this encoding -- including in peripheral vision -- may help us finally make sense of the puzzling strengths and limitations of visual perception.

The role of spatial ensemble statistics in visual working memory and scene perception

Speaker: Tim Brady, University of California-San Diego

At any given moment, much of the relevant information about the visual world is in the periphery rather than the fovea. The periphery is particularly useful for providing information about scene structure and spatial layout, as well as informing us about the spatial distribution and features of the objects we are not explicitly attending and fixating. What is the nature of our representation of this information about scene structure and the spatial distribution of objects? In this talk, I'll discuss evidence that representations of the spatial distribution of simple visual features (like orientation, spatial frequency, color), termed spatial ensemble statistics, are specifically related to our ability to quickly and accurately recognize visual scenes. I'll also show that these spatial ensemble statistics are a critical part of the information we maintain in visual working memory – providing information about the entire set of objects, not just a select few, across eye movements, blinks, occlusions and other interruptions of the visual scene.

Summary Statistics in the Periphery: A Metacognitive Approach

Speaker: Brian Odegaard, University of California-Los Angeles

Recent evidence indicates that human observers often overestimate their capacity to make perceptual judgments in the visual periphery. How can we quantify the degree to which this overestimation occurs? We describe how applications of Signal Detection Theoretic frameworks provide one promising approach to measure both detection biases and task performance capacities for peripheral stimuli. By combining these techniques with new metacognitive measures of perceptual confidence (such as meta-d'; Maniscalco & Lau, 2012), one can obtain a clearer picture regarding (1) when subjects can simply perform perceptual tasks in the periphery, and (2) when they have true metacognitive awareness of the visual surround. In this talk, we describe results from recent experiments employing these quantitative techniques, comparing and contrasting the visual system's capacity to encode summary statistics in both the center and periphery of the visual field.

S5 - Cutting across the top-down-bottom-up dichotomy in attentional capture research

Friday, May 19, 2017, 5:00 - 7:00 pm, Talk Room 1

Organizer(s): J. Eric T. Taylor, Brain and Mind Institute at Western University

Presenters: Nicholas Gaspelin, Matthew Hilchey, Dominique Lamy, Stefanie Becker, Andrew B. Leber

Research on attentional selection describes the various factors that determine what information is ignored and what information is processed. These factors are commonly described as either bottom-up or top-down, indicating whether stimulus properties or an observer's goals determine the outcome of selection. Research on selection typically adheres strongly to one of these two perspectives; the field is divided. The aim of this symposium is to generate discussions and highlight new developments in the study of attentional selection that do not conform to the bifurcated approach that has characterized the field for some time (or trifurcated, with respect to recent models emphasizing the role of selection history). The research presented in this symposium does not presuppose that selection can be easily or meaningfully dichotomized. As such, the theme of the symposium is cutting across the top-down-bottom-up dichotomy in attentional selection research. To achieve this, presenters in this session either share data that cannot be easily explained within the top-down or bottom-up framework, or they propose alternative models of existing descriptions of sources of attentional control. Theoretically, the symposium will begin with presentations that attempt to resolve the dichotomy with a new role for suppression (Gaspelin & Luck) or further bemuse the dichotomy with typically bottom-up patterns of behaviour in response to intransient stimuli (Hilchey, Taylor, & Pratt). The discussion then turns to demonstrations that the bottom-up, top-down, and selection history sources of control variously operate on different perceptual and attentional processes (Lamy & Zivony; Becker & Martin), complicating our categorization of sources of control. Finally, the session will conclude with an argument for more thorough descriptions of sources of control (Leber & Irons). In summary, these researchers will present cutting-edge developments using converging methodologies (chronometry, EEG, and eye-tracking measures) that further our understanding of attentional selection and advance attentional capture research beyond its current dichotomy. Given the heated history of this debate and the importance of the theoretical question, we expect that this symposium should be of interest to a wide audience of researchers at VSS, especially those interested in visual attention and cognitive control.

Mechanisms underlying suppression of attentional capture by salient stimuli

Speaker: Nicholas Gaspelin, Center for Mind and Brain at the University of California, Davis

Additional Authors: Nicholas Gaspelin, Center for Mind and Brain at the University of California, Davis; Carly J. Leonard, Center for Mind and Brain at the University of California, Davis; Steven J. Luck, Center for Mind and Brain at the University of California, Davis

Researchers have long debated the nature of cognitive control in vision, with the field being dominated by two theoretical camps. Stimulus-driven theories claim that visual attention is automatically captured by salient stimuli, whereas goal-driven theories argue that capture depends critically the goals of a viewer. To resolve this debate, we have previously provided key evidence for a new hybrid model called signal suppression hypothesis. According to this account, all salient stimuli generate an active salience signal which automatically attempts to guide visual attention. However, this signal can be actively suppressed. In the current talk, we review the converging evidence for this active suppression of salient items, using behavioral, eye tracking and electrophysiological methods. We will also discuss the cognitive mechanisms underlying suppression effects and directions for future research.

Beyond the new-event paradigm in visual attention research: Can completely static stimuli capture attention?

Speaker: Matthew Hilchey, University of Toronto

Additional Authors: Matthew D. Hilchey, University of Toronto, J. Eric T. Taylor, Brain and Mind Institute at Western University; Jay Pratt, University of Toronto

The last several decades of attention research have focused almost exclusively on paradigms that introduce new perceptual objects or salient sensory changes to the visual environment in order to determine how attention is captured to those locations. There are a handful of exceptions, and in the spirit of those studies, we asked whether or not a completely unchanging stimuli can attract attention using variations of classic additional singleton and cueing paradigms. In the additional singleton tasks, we presented a preview array of six uniform circles. After a short delay, one circle changed in form and luminance – the target location – and all but one location changed luminance, leaving the sixth location physically unchanged. The results indicated that attention was attracted toward the vicinity of the only unchanging stimulus, regardless of whether all circles around it increased or decreased luminance. In the cueing tasks, cueing was achieved by changing the luminance of 5 circles in the object preview array either 150 or 1000 ms before the onset of a target. Under certain conditions, we observed canonical patterns of facilitation and inhibition emerging from the location containing the physically unchanging cue stimuli. Taken together, the findings suggest that a completely unchanging stimulus, which bears no obvious resemblance to the target, can attract attention in certain situations.

Stimulus salience, current goals and selection history do not affect the same perceptual processes

Speaker: Dominique Lamy, Tel Aviv University

Additional Authors: Dominique Lamy, Tel Aviv University Alon Zivony, Tel Aviv University

When exposed to a visual scene, our perceptual system performs several successive processes. During the preattentive stage, the attentional priority accruing to each location is computed. Then, attention is shifted towards the highest-priority location. Finally, the visual properties at that location are processed. Although most attention models posit that stimulus-driven and goal-directed processes combine to determine attentional priority, demonstrations of purely stimulus-driven capture are surprisingly rare. In addition, the consequences of stimulus-driven and goal-directed capture on perceptual processing have not been fully described. Specifically, whether attention can be disengaged from a distractor before its properties have been processed is unclear. Finally, the strict dichotomy between bottom-up and top-down attentional control has been challenged based on the claim that selection history also biases attentional weights on the priority map. Our objective was to clarify what perceptual processes stimulus salience, current goals and selection history affect. We used a feature-search spatial-cueing paradigm. We showed that (a) unlike stimulus salience and current goals, selection history does not modulate attentional priority, but only perceptual processes following attentional selection; (b) a salient distractor not matching search goals may capture attention but attention can be disengaged from this distractor's location before its properties are fully processed; and (c) attentional capture by a distractor sharing the target feature entails that this distractor's properties are mandatorily processed.

Which features guide visual attention, and how do they do it?

Speaker: Stefanie Becker, The University of Queensland

Additional Authors: Stefanie Becker, The University of Queensland; Aimee Martin, The University of Queensland

Previous studies purport to show that salient irrelevant items can attract attention involuntarily, against the intentions and goals of an observer. However, corresponding evidence originates predominantly from RT and eye movement studies, whereas EEG studies largely failed to support saliency capture. In the present study, we examined effects of salient colour distractors on search for a known colour target when the distractor was similar vs. dissimilar to the target. We used both eye tracking and EEG (in separate experiments), and also investigated participant's awareness of the features of irrelevant distractors. The results showed that capture by irrelevant distractors was strongly top-down modulated, with target-similar distractors attracting attention much more strongly, and being remembered better, than salient distractors. Awareness of the distractor correlated more strongly with initial capture rather than attentional dwelling on the distractor after it was selected. The salient distractor enjoyed no noticeable advantage over non-salient control distractors with regard to implicit measures, but was overall reported with higher accuracy than non-salient distractors. This raises the interesting possibility that salient items may primarily boost visual processes directly, by requiring less attention for accurate perception, not by summoning spatial attention.

Toward a profile of goal-directed attentional control

Speaker: Andrew B. Leber, The Ohio State University

Additional Authors: Andrew B. Leber, The Ohio State University; Jessica L. Irons, The Ohio State University

Recent criticism of the classic bottom-up/top-down dichotomy of attention has deservedly focused on the existence of experience-driven factors outside this dichotomy. However, as researchers seek a better framework characterizing all control sources, a thorough re-evaluation of the top-down, or goal-directed, component is imperative. Studies of this component have richly documented the ways in which goals strategically modulate attentional control, but surprisingly little is known about how individuals arrive at their chosen strategies. Consider that manipulating goal-directed control commonly relies on experimenter instruction, which lacks ecological validity and may not always be complied with. To better characterize the factors governing goal-directed control, we recently created the adaptive choice visual search paradigm. Here, observers can freely choose between two targets on each trial, while we cyclically vary the relative efficacy of searching for each target. That is, on some trials it is faster to search for a red target than a blue target, while on other trials the opposite is true. Results using this paradigm have shown that choice behavior is far from optimal, and appears largely determined by competing drives to maximize performance and minimize effort. Further, individual differences in performance are stable across sessions while also being malleable to experimental manipulations emphasizing one competing drive (e.g., reward, which motivates individuals to maximize performance). This research represents an initial step toward characterizing an individual profile of goal-directed control that extends beyond the classic understanding of "top-down" attention and promises to contribute to a more accurate framework of attentional control.

S6 - Virtual Reality and Vision Science

Friday, May 19, 2017, 5:00 - 7:00 pm, Pavilion

Organizer(s): Bas Rokers, University of Wisconsin - Madison & Karen B. Schloss, University of Wisconsin - Madison

Presenters: Jacqueline Fulvio, Robin Held, Emily Cooper, Stefano Baldassi, David Luebke

Virtual reality (VR) and augmented reality (AR) provide exciting new opportunities for vision research. In VR sensory cues are presented to simulate an observer's presence in a virtual environment. In AR sensory cues are presented that embed virtual stimuli in the real world. This symposium will bring together speakers from academia and industry to present new scientific discoveries enabled by VR/AR technology, discuss recent and forthcoming advances in the technology, and identify exciting new avenues of inquiry. From a basic research perspective, VR and AR allow us to answer fundamental scientific questions that have been difficult or impossible to address in the past. VR/AR headsets provide a number of potential benefits over traditional psychophysical methods, such as incorporating a large field of view, high frame rate/low persistence, and low latency head tracking. These technological innovations facilitate experimental research in highly controlled, yet naturalistic three-dimensional environments. However, VR/AR also introduces its own set of unique challenges of which potential researchers should be aware. Speakers from academia will discuss ways they have used VR/AR as a tool to advance knowledge about 3D perception, multisensory integration, and navigation in naturalistic three-dimensional environments. Speakers will also present research on perceptual learning and neural plasticity, which may benefit from training in cue-rich environments that simulate real-world conditions. These talks will shed light on how VR/AR may ultimately be used to mitigate visual deficits and contribute to the treatment of visual disorders. Speakers from industry will highlight recent technological advances that can make VR such a powerful tool for research. Industry has made significant strides solving engineering problems involving latency, field of view, and presence. However, challenges remain, such as resolving cue conflicts and eliminating motion sickness. Although some of these issues may be solved through engineering, others are due to limitations of the visual system and require solutions informed by basic research within the vision science community. This symposium aims to provide a platform that deepens the dialog between academia and industry. VR holds unprecedented potential for building assistive technologies that will aid people with sensory and cognitive disabilities. Hearing from speakers in industry will give vision scientists an overview of anticipated technological developments, which will help them evaluate how they may incorporate VR/AR in their future research. In turn vision researchers may help identify science-based solutions to current engineering challenges. In sum this symposium will bring together two communities for the mutually beneficial advancement of VR-based research. Who may want to attend: This symposium will be of interest to researchers who wish to consider incorporating AR/VR into their research, get an overview of existing challenges, and get a sense of future directions of mutual interest to industry and academia. The talks will be valuable to researchers at all stages of their careers. Hearing from representatives from both industry and academia may be useful for early stage researchers seeking opportunities beyond the highly competitive academic marketplace and may help researchers at all stages identify funding sources in the highly competitive granting landscape.

Extra-retinal cues improve accuracy of 3D motion perception in virtual reality environments

Speaker: Jacqueline Fulvio, University of Wisconsin - Madison

Additional Authors: Jacqueline M. Fulvio & Bas Rokers, Department of Psychology, UW-Madison

Our senses provide imperfect information about the world that surrounds us, but we can improve the accuracy of our perception by combining sensory information from multiple sources. Unfortunately, much of the research in visual perception has utilized methods of stimulus presentation that eliminate potential sources of information. It is often the case for example, that observers are asked to maintain a fixed head position while viewing stimuli generated on flat 2D displays. We will present recent work on the perception of 3D motion using the Oculus Rift, a virtual reality (VR) head-mounted display with head-tracking functionality. We describe the impact of uncertainty in visual cues presented in isolation, which have surprising consequences for the accuracy of 3D motion perception. We will then describe how extra-retinal cues, such as head motion, improve visual accuracy. We will conclude with a discussion of the potential and limitations of VR technology for the understanding visual perception.

Perceptual considerations for the design of mixed-reality content

Speaker: Robin Held, Microsoft

Additional Authors: Robin Held, Microsoft

Virtual-reality head-mounted displays (VR HMDs) block out the real world while engulfing the user in a purely digital setting. Meanwhile, mixed-reality (MR) HMDs embed digital content within the real-world while maintaining the user's perception of her or his surroundings. This ability to simultaneously perceive both rendered content and real objects presents unique challenges for the design of MR content. I will briefly review the technologies underlying current MR headsets, including display hardware, tracking systems, and spatial audio. I will also discuss how the existing implementations of those technologies impact the user's perception of the content. Finally, I will show how to apply that knowledge to optimize MR content for comfort and aesthetics.

Designing and assessing near-eye displays to increase user inclusivity

Speaker: Emily Cooper, Dartmouth College

Additional Authors: Nitish Padmanaban, Robert Konrad, and Gordon Wetzstein, Department of Electrical Engineering, Stanford University

From the desktop to the laptop to the mobile device, personal computing platforms evolve over time. But in each case, one thing stays the same: the primary interface between the computer and the user is a visual display. Recent years have seen impressive growth in near-eye display systems, which are the basis of most virtual and augmented reality experiences. There are, however, a unique set of challenges to designing a display that is literally strapped to the user's face. With an estimated half of all adults in the United States requiring some level of visual correction, maximizing inclusivity for near-eye displays is essential. I will describe work that combines principles from optics, optometry, and visual perception to identify and address major limitations of near-eye displays both for users with normal vision and those that require common corrective lenses. I will also describe ongoing work assessing the potential for near-eye displays to assist people with less common visual impairments at performing day-to-day tasks.

See-through Wearable Augmented Reality: challenges and opportunities for vision science

Speaker: Stefano Baldassi, Meta Company

Additional Authors: Stefano Baldassi & Moqian Tian, Analytics & Neuroscience Department, Meta Company

We will present Meta's Augmented Reality technology and the challenges faced in product development that may generate strong mutual connections between vision science and technology, as well as new areas of research for vision science and research methods using AR. The first line of challenges comes from the overlap between virtual content and the real world due to the non-opacity of the rendered pixels and the see-through optics. What are the optimal luminance, contrast and color profile to enable least interference? Will the solutions be qualitatively different in photonic and scotopic conditions? With SLAM, the virtual objects can be locked onto the real scene. Does the real world provide the same environmental context to the virtual object as a real object? Last, what are the implication of digital content in the periphery, given Meta's industry-leading 90° FOV? The second line of challenges is in the domain of perception and action and multi-sensory integration. Meta supports manipulation of virtual objects. In the absence of haptic stimulation, when hands interact with the virtual object we currently rely on visual and proprioceptive cues to guide touch. How is the visuo-motor control of hands affected by manipulations without haptics? In order to enable people to interact with the virtual objects realistically and effectively, are cues like occlusion and haptic feedback necessary? Will time locked sound introduce valuable cues?

COMPUTATIONAL DISPLAY FOR VIRTUAL AND AUGMENTED REALITY

Speaker: David Luebke, NVIDIA
Additional Authors: David Luebke, VP Graphics Research, NVIDIA

Wearable displays for virtual & augmented reality face tremendous challenges, including: Near-Eye Display: how to put a display as close to the eye as a pair of eyeglasses, where we cannot bring it into focus? Field of view: how to fill the user's entire vision with displayed content? Resolution: how to fill that wide field of view with enough pixels, and how to render all of those pixels? A "brute force" display would require 10,000×8,000 pixels per eye! Bulk: displays should be as unobtrusive as sunglasses, but optics dictate that most VR displays today are bigger than ski goggles. Focus cues: today's VR displays provide binocular display but only a fixed optical depth, thus missing the monocular depth cues from defocus blur and introducing vergence-accommodation conflict. To overcome these challenges requires understanding and innovation in vision science, optics, display technology, and computer graphics. I will describe several "computational display" VR/AR prototypes in which we co-design the optics, display, and rendering algorithm with the human visual system to achieve new tradeoffs. These include light field displays, which sacrifice spatial resolution to provide thin near-eye display and focus cues; pinlight displays, which use a novel and very simple optical stack to produce wide field-of-view see-through display; and a new approach to foveated rendering, which uses eye tracking and renders the peripheral image with less detail than the foveal region. I'll also talk about our current efforts to "operationalize" vision science research, which focuses on peripheral vision, crowding, and saccadic suppression artifacts.

Saturday Morning Talks

Perception and Action: Arm movements

Saturday, May 20, 8:15 - 9:45 am
Talk Session, Talk Room 1
Moderator: Robert Volcic

21.11, *8:15 am* **The causal role of the lateral occipital (LO) cortex and anterior intraparietal sulcus (aIPS) in real and pantomimed grasping: an fMRI-guided TMS study** Diana Tonin[1](D.tonin@uea.ac.uk), Vincenzo Romei[2], Rachel Lambert[1], Andre Bester[1], Janak Saada[3], Stephanie Rossit[1]; [1]School of Psychology, University of East Anglia, Norwich, UK, [2]Department of Psychology, Centre for Brain Science, University of Essex, Colchester, UK, [3]Department of Radiology, Norfolk and Norwich University Hospital, Norwich, UK

Milner and Goodale (1995) propose a model of vision that makes a distinction between vision for perception and vision for action. One strong claim of this model is that the visual processing of objects for real grasping depends on dorsal stream areas whereas the processing of objects for pantomimed actions depends on the ventral stream regions. However, and even more that 20 years after its formulation, this claim is largely based on a single-case neuropsychological study: visual form agnosic patient DF can scale her grip aperture to different object sizes during real visually-guided grasping, but her grip scaling is impaired when performing pantomimed grasping in a location adjacent to these same objects. Here we used fMRI-guided transcranial magnetic stimulation (TMS) to shed light on the specific role of the lateral occipital (LO) cortex, a key ventral stream area in object perception, and the anterior intraparietal sulcus (aIPS), a key dorsal stream region in grip scaling, in real and pantomimed grasping. We applied theta burst TMS over left aIPS, left LO or vertex in three separate sessions before 16 participants performed real object grasping and pantomimed grasping in an adjacent location to the presented object. Grasping movements were performed in open loop with the right-hand in response to 3D Efron blocks presented in the right visual field. For real grasping, TMS over aIPS significantly weakened the relationship between object size and grip aperture when compared to TMS over LO and TMS over vertex, whereas TMS over LO had no effects. For pantomimed grasping, TMS over both aIPS and LO considerably reduced the relationship between object size and grip aperture when compared to vertex stimulation. Our results show that while aIPS is causally involved in grip scaling for both real and pantomime grasping, LO is only involved in pantomimed grasping.

21.12, *8:30 am* **Proprioception calibrates object size constancy for grasping but not perception in limited viewing conditions** Juan Chen[1](jchen737@uwo.ca), Irene Sperandio[2], Melvyn Goodale[1]; [1]The Brain and Mind Institute, The University of Western Ontario, London, Ontario, Canada, [2]School of Psychology, University of East Anglia, Norwich, UK

Observers typically perceive an object as being the same size even when it is viewed at different distances. What is seldom appreciated, however, is that people also use the same grip aperture when grasping an object positioned at different viewing distances in peripersonal space. Perceptual size constancy has been shown to depend on a range of distance cues, each of which will be weighted differently in different viewing conditions. What is not known, however, is whether or not the same distance cues (and the same cue weighting) are used to calibrate size constancy for grasping. To address this question, participants were asked either to grasp or to manually estimate (using their right hand) the size of spheres presented at different distances in a full-viewing condition (light on, binocular viewing) or in a limited-viewing condition (light off, monocular viewing through a 1 mm hole). In the full-viewing condition, participants showed size constancy in both tasks. In the limited-viewing condition, participants no longer showed size constancy, opening their hand wider when the object was closer in both tasks. This suggests that binocular and other visual cues contribute to size constancy in both grasping and perceptual tasks. We then asked participants to perform the same tasks while their left hand was holding a pedestal under the sphere. Remarkably, the proprioceptive cues from holding the pedestal with their left hand dramatically restored size constancy in the grasping task but not in the manual estimation task. These results suggest that proprioceptive information can support size constancy in grasping when visual distance cues are severely limited, but such cues are not sufficient to support size constancy in perception.

Acknowledgement: This work was supported by a discovery grant from the Natural Sciences and Engineering Research Council of Canada (NSERC) to M.A.G. and the

21.13, *8:45 am* **The medial grasping area in the parietal cortex of the macaque** Patrizia Fattori[1](patrizia.fattori@unibo.it), Rossella Breveglieri[1], Marina De Vitis[1], Annalisa Bosco[1], Claudio Galletti[1]; [1]Dept. Pharmacy and Biotechnology, University of Bologna, Italy

The parietal lobe hosts different areas involved in linking sensory information to signals useful to control arm movements. One area of the inferior parietal lobule, area AIP, is the parietal grasping area for antonomasia. Recently, also one area of the superior parietal lobule, area V6A, has been found to be involved in encoding grasping (Fattori et al., 2010 J. Neurosci; Fattori et al., 2012 J. Neurosci). In this work, we tested grasping responses of single V6A neurons with the same tasks used to study the lateral grasping area AIP (Murata et al., 2000 J. Neurophysiol). Delayed grasping actions were performed by two monkeys towards five objects of different shapes (so to require different grip types) either in full vision or in complete darkness. In a second task, the same objects were observed without performing grasping. We recorded 200 V6A neurons, and quantified the neural activity during grasping preparation, execution, and object holding and during object observation. The overwhelming majority of neurons (94%) resulted to be task-related. Most of task-related cells were influenced by visual background. Half of the neurons were excited by the visual input, half were inhibited. Similarly to AIP, V6A contains Visual cells, activated only during grasping in light; Motor neurons, equally activated during grasping in dark and in light; Visuomotor cells, differently activated while grasping in dark and in light. A subpopulation of grasp-related cells discharged also while the monkey observed the objects outside the grasping context. Most of the Visual, Motor, and Visuomotor neurons, highly or moderately selective for the object during grasping, lost their selectivity during object observation. A frame emerges where the two grasping parietal areas share some functional properties useful to update and control prehension, as the hand approaches an object, but with a different weight of sensory signals.

Acknowledgement: MIUR (PRIN and FIRB) EU FP7-IST-217077-EYESHOTS

21.14, *9:00 am* **Modeling Hand-Eye Movements in a Virtual Ball Catching Setup using Deep Recurrent Neural Network** Kamran Binaee[1](kamranbinaee@mail.rit.edu), Anna Starynska[1], Rakshit Kothari[1], Christopher Kanan[1], Jeff Pelz[1], Gabriel Diaz[1]; [1]Rochester Institute of Technology, Chester F. Carlson Center for Imaging Science

Previous studies show that humans efficiently formulate predictive strategies to make accurate eye/hand movements when intercepting with a target moving in their field of view, such as a ball in flight. Nevertheless, it is not clear how these strategies compensate for noisy sensory input and how long these strategies are valid in time, as when a ball is occluded mid-flight prior to an attempted catch. To investigate, we used a Virtual Reality ball catching paradigm to record the 3D gaze of ten subjects as well as their head and hand movements. Subjects were instructed to intercept a virtual ball in flight while wearing a head mounted display which was being tracked using motion capture system. Midway through its parabolic trajectory, the ball was made invisible for a blank duration of 500 ms. We created 9 different ball trajectories by choosing three pre-blank (300, 400, 500 ms) and three post-blank durations (600, 800, 1000 ms). The ball launch position and angle were randomized. During the blank, average angular displacement of the ball was 11 degrees of visual angle. In this period subjects were able to track the ball successfully using head+eye pursuit. In success trials, subjects have higher smooth pursuit gain values during the blank, combined with a sequence of saccades in the direction of ball trajectory toward the end of the trial. Approximately 200 ms before the catching frame, angular gaze-ball tracking error in elevation, forecasts subject's success or failure. We used this dataset to train a deep Recurrent Neural Network (RNN) that

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models human hand-eye movements. By using previous input sequences, the RNN model predicts the angular gaze vector and hand position for a short duration into the future. Consistent with studies of human behavior, the proposed model accuracy decreases when we extend the prediction window beyond 120 ms.

21.15, *9:15 am* **Congruency between perceptual and conceptual object size modulates visually-guided action** Christine Gamble[1](christine_gamble@brown.edu), Joo-Hyun Song[1,2]; [1]Cognitive, Linguistic, and Psychological Sciences Department, Brown University, [2]Brown Institute for Brain Science, Brown University

In daily interactions with the world around us, object sizes critically affect the kinematics and dynamics of goal-directed movements such as pointing or grasping. For instance, ballistic pointing movements are faster the larger their target is (Fitts, 1955). However, because the perceptual and conceptual sizes of objects are mostly consistent in the real world—elephants are almost always perceived and conceptualized as larger than rabbits—it is not clear if we guide movements solely based on our assessment of perceptual size, or if objects' higher-order conceptual sizes also influence action. Here, we compared pointing movements directed at images of real-world objects when their relative perceptual sizes were either congruent or incongruent with their relative conceptual sizes (e.g. an elephant was presented as perceptually larger or smaller than a rabbit, respectively). Participants were instructed to point to the larger or smaller of two simultaneously presented objects in perceptual and conceptual size judgment tasks. We observed that participants pointed to target objects faster when their perceptual and conceptual sizes were congruent compared to incongruent. Furthermore, we demonstrated that when perceptual and conceptual sizes were incongruent, pointing movements were more attracted towards the incorrect object (e.g. in the larger perceptual size judgment task, the conceptually larger but perceptually smaller object), leading to more curved trajectories. These results were observed in both the perceptual and conceptual size judgment tasks, consistent with prior research showing that perceptual size judgments are impaired when object size is inconsistent with object knowledge (Konkle and Oliva, 2012). Despite this interactive modulation of goal-directed pointing by perceptual and conceptual size, we observed greater overall competition (i.e. curvature), in the conceptual size judgment task. Thus, we propose that assessments of perceptual size have greater influence on action than assessments of real-world conceptual size, despite the fact that both are performed automatically.

21.16, *9:30 am* **Errors in manual interception are precisely what one would expect for the psychophysically determined errors in perception** Cristina de la Malla[1], Jeroen Smeets[1], Eli Brenner[1]; [1]Department of Human Movement Sciences, Vrije Universiteit Amsterdam

Visual illusions influence the way we perceive things. They can also influence the way we move. Whether illusions influence perception and action to the same extent is still under debate. A major difficulty in resolving this debate is that it only makes sense to compare the influences if one knows how the action is based on the attribute that is influenced by the illusion. We therefore used what we know about how visual information guides the hand in interception to examine whether psychophysical estimates of the extent to which a two-dimensional Gabor patch (a sinusoidal grating of which the luminance contrast is modulated by a two-dimensional Gaussian) is perceived to move at a different velocity than its true velocity when the grating moves within the Gaussian can explain the errors that people make when trying to intercept such Gabor patches. In separate two-interval forced choice discrimination tasks we measured how moving the grating influenced the perceived position and the perceived velocity of the target. When the grating moved in the same direction as the patch, the patch was judged to move faster than it really was. When it moved in the opposite direction, it was judged to move more slowly. The perceived position was hardly affected. We calculated the errors that subjects would make if they used these judgements to predict the motion of the moving patch during the last 100 ms of an interceptive action (when movements can no longer be corrected due to sensorimotor delays). We compared these predicted errors with the errors that subjects actually made when they had to intercept similar targets. The predicted errors closely matched the actual errors in interception. We conclude that errors in perceiving how a target moves lead to the errors that one would expect in an action directed towards such targets.

Acknowledgement: NWO 464-13-169

FACE PERCEPTION: EXPERIENCE AND DISORDERS

Saturday, May 20, 8:15 - 9:45 am
Talk Session, Talk Room 2
Moderator: Isabel Gauthier

21.21, *8:15 am* **The speed of continuous face detection suggests shortcuts in the visual hierarchy for upright faces** Jacob Martin[1](jacobgmartin@gmail.com), Charles Davis[1], Maximilian Riesenhuber[2], Simon Thorpe[1]; [1]CerCo, CNRS, [2]Department of Neuroscience, Georgetown University Medical Center

The detection of faces in the visual field is a key cognitive task of high ecological importance. While a number of studies have shown human subjects' impressive ability to detect faces in individual images, we here report evidence that subjects are able to rapidly saccade towards 4000 faces continuously at rates approaching 6 faces a second when there is no background (including the time for blinks and eye movements). Surprisingly, pasting or hiding the faces by blending them into a large background pictures had little effect on detection rates, saccade reaction times, or accuracy. Saccade reaction times were similar to the "ultra-rapid" saccades found in studies which utilized pauses and fixations between experimental trials (Crouzet et al. 2010). Upright faces were found more quickly and more accurately than inverted faces; both with and without a cluttered background, and over a large range of eccentricities (4°-16°). These results argue for the existence of a face-selective shortcut in the visual hierarchy which enables ultra-rapid and high-throughput face detection.

Acknowledgement: ERC Advanced Grant No323711 (M4), NSF NEI R01EY024161

21.22, *8:30 am* **Thickness of deep layers in FFA predicts face recognition performance** Isabel Gauthier[1](isabel.gauthier@vanderbilt.edu), Rankin McGugin[1], Benjamin Tamber-Rosenau[2], Allen Newton[3]; [1]Department of Psychology, Vanderbilt University, Nashville, TN, USA, [2]Department of Psychology, University of Houston, Houston, TX, USA, [3]Department of Radiology and Radiological Sciences, Vanderbilt University, Nashville, TN, USA

Individual differences in expertise with non-face objects has been positively related to neural selectivity for these objects in several brain regions, including in the fusiform face area (FFA). Recently, we reported that FFA's cortical thickness is also positively correlated with expertise for non-living objects, while FFA's cortical thickness is negatively correlated with face recognition ability. These opposite relations between structure and visual abilities, obtained in the same subjects, were postulated to reflect the earlier experience with faces relative to cars, with different mechanisms of plasticity operating at these different developmental times. Here we predicted that variability for faces, presumably reflecting pruning, would be found selectively in deep cortical layers. In 13 men selected to vary in their performance with faces, we used ultra-high field imaging (7 Tesla), we localized the FFA functionally and collected and averaged 6 ultra-high resolution susceptibility weighed images (SWI). Voxel dimensions were 0.194x0.194x1.00mm, covering 20 slices with 0.1mm gap. Images were then processed by two operators blind to behavioral results to define the gray matter/white matter (deep) and gray matter/CSF (superficial) cortical boundaries. Internal boundaries between presumed deep, middle and superficial cortical layers were obtained with an automated method based on image intensities. We used an extensive battery of behavioral tests to quantify both face and object recognition ability. We replicate prior work with face and non-living object recognition predicting large and independent parts of the variance in cortical thickness of the right FFA, in different directions. We also find that face recognition is specifically predicted by the thickness of the deep cortical layers in FFA, whereas recognition of vehicles relates to the thickness of all cortical layers. Our results represent the most precise structural correlate of a behavioral ability to date, linking face recognition ability to a specific layer of a functionally-defined area.

Acknowledgement: This work was supported by the NSF (SBE-0542013 and SMA-1640681) and the Vanderbilt Vision Research Center (P30-EY008126)

21.23, *8:45 am* **Hemispheric specialization for faces in pre-reading children** Aliette Lochy[1](aliette.lochy@uclouvain.be), Adelaide de Heering[2], Bruno Rossion[1]; [1]Psychological Sciences Research Institute, Institute of Neuroscience, University of Louvain, Belgium, [2]UNESCOG/CRCN, Université Libre de Bruxelles, Belgium

The developmental origin of the human right hemispheric lateralization for face perception remains unclear. According to a recent hypothesis, the increase in left lateralized posterior neural activity during reading acquisition contributes to, or even determines, the right hemispheric lateralization for face perception (Behrmann & Plaut, 2013). This view contrasts with the right hemispheric advantage observed in few months old infant. Recently, a Fast Visual Periodic Stimulation (FPVS) paradigm in EEG showed that periodically presented faces among objects lead to strongly right lateralized face-selective responses in 4-6 months old infants (de Heering & Rossion, 2015). Here we used the exact same paradigm in EEG to study the lateralization of responses to faces in a group (N=35) of 5 years-old pre-school children showing left-lateralized responses to letters (Lochy et al., 2016). Rather surprisingly, we found bilateral face-selective responses in this population, with a small positive correlation found between preschool letter knowledge and right hemispheric lateralization for faces (rho=0.30; p< 0.04), but no correlation between the left lateralization to letters and the right lateralization to faces. However, discrimination of facial identity with FPVS (Liu-Shuang et al., 2014) in these pre-reading children was strongly right lateralized, and unrelated to their letter knowledge. These findings suggest that other factors than reading acquisition, such as the posterior corpus callosum maturation during early childhood as well as the level required by the perceptual categorization process (i.e., generic face categorization vs. face individualization), play a key role in the right hemispheric lateralization for face perception in humans.

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21.24, *9:00 am* **Development of neural sensitivity to face identity correlates with perceptual discriminability** Vaidehi Natu[1](vnatu@stanford.edu), Michael Barnett[1], Jake Hartley[1], Jesse Gomez[2], Anthony Stigliani[1], Kalanit Grill-Spector[1,2,3]; [1]Department of Psychology, Stanford University, Stanford, CA 94305, [2]Neurosciences Program, Stanford University School of Medicine, [3]Stanford Neurosciences Institute, Stanford University, Stanford, CA 94305

Face-selective regions in the human ventral stream undergo prolonged development from childhood to adulthood. Children also show protracted development of face perception. However, the neural mechanisms underlying the perceptual development remain unknown. Here, we asked if development is associated with changes in neural sensitivity to face identity, or changes in the overall level of response to faces, or both. Using fMRI, we measured brain responses in ventral face-selective regions (IOG-faces, pFus-faces, and mFus-faces) and two object-selective regions (pFs-objects and LO-objects, as control regions) in children (ages 5-12, N=23) and adults (ages 22-34, N=12), when they viewed adult and child faces, which parametrically varied in the amount of dissimilarity. Since similar faces generate lower responses than dissimilar faces due to fMRI-adaptation, it can be used to study neural sensitivity across age groups. Additionally, a subset of participants (12 children; 11 adults) participated in a behavioral experiment conducted to assess perceptual discriminability of face identity. Our data reveal the following main findings: (1) in both children and adults, responses in ventral face-selective regions linearly increased with face dissimilarity (Fig. 1a), (2) neural sensitivity to face identity increased with age in face- but not object-selective regions (Fig. 1b), (3) the amplitude of responses to faces increased with age in both face- and object-selective regions (Fig. 1c) and (4) perceptual discriminability of face identity was correlated with the neural sensitivity to face identity of face-selective regions (Fig. 1d). Our results suggest that developmental increases in neural sensitivity to face identity in face-selective regions improves perceptual discriminability of faces. These findings significantly advance understanding of neural mechanisms underlying the development of face perception and have important implications for assessing development in neural mechanisms of high-level cortical areas.

Acknowledgement: NIH Grants: 1RO1EY 02231801A1, 1R01EY02391501A1 and 5T32EY020485 NSF Grant: DGE-114747.

21.25, *9:15 am* **Deafness Amplifies Visual Information Sampling during Face Recognition** Junpeng Lao[1](junpeng.lao@unifr.ch), Chloé Stoll[2], Matthew Dye[3], Olivier Pascalis[2], Roberto Caldara[1]; [1]Eye and Brain Mapping Laboratory (iBMLab), Department of Psychology, University of Fribourg, Fribourg, Switzerland, [2]Laboratoire de Psychologie et Neurocognition (CNRS), Université Grenoble Alpes, Grenoble, France, [3]Rochester Institute of Technology/National Technical Institute for Deaf, Rochester, New York, USA

We move our eyes to navigate, identify dangers, objects and people in a wide range of situations during social interactions. However, the extent to which visual sampling is modulated and shaped by non-visual information is difficult to control. A particular fate of nature might be helpful to achieve this feat: the occurrence of deafness. Research has shown that early profound hearing loss enhances the sensitivity and efficiency of the visual channel in deaf individuals, resulting in a larger peripheral visual attention compared to the hearing population (Dye et al., 2009). However, whether such perceptual bias extends to visual sampling strategies deployed during the biologically-relevant face recognition task remains to be clarified. To this aim, we recorded the eye movements of deaf and hearing observers while they performed a delayed matching task with upright and inverted faces. Deaf observers showed a preferential central fixation pattern compared to hearing controls, with the spatial fixation density peaking just below the eyes. Interestingly, even unlike hearing observers presenting a global fixation pattern, the deaf observers were not impaired by the face inversion and did not change their sampling strategy. To assess whether this particular fixation strategy in the deaf observers was paired with a larger information intake, the same participants performed the identical experiment with a gaze-contingent paradigm parametrically and dynamically modulating the quantity of information available at each fixation – the Expanding Spotlight (Miellet et al. 2013). Visual information reconstruction with a retinal filter revealed an enlarged visual field in deafness. Unlike hearing participants, deaf observers used larger information intake from all the fixations. This visual sampling strategy was robust and as effective for inverted face recognition. Altogether, our data show that the face system is flexible and might tune to distinct strategies as a function of visual and social experience.

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21.26, *9:30 am* **Is face perception preserved in pure alexia? Evaluating complementary contribution of the left fusiform gyrus to face processing** Andrea Albonico[1,2](nea.albonico@gmail.com), Jason Barton[1]; [1]Human Vision and Eye Movement Laboratory, Departments of Medicine (Neurology), Ophthalmology and Visual Sciences, University of British Columbia, Vancouver, Canada, [2]NeuroMI - Milan Center for Neuroscience, Milano, Italy

Face recognition and reading are two expert forms of human visual processing. Recent evidence show that they involve overlapping cerebral networks in the right and left hemispheres, leading the many-to-many hypothesis to predict that a lesion to the left fusiform gyrus that causes pure alexia will also be associated with mild impairments in face processing. Our goal was to determine if alexic subjects showed face identity processing deficits similar but milder to those seen in prosopagnosia following right fusiform lesions, or if they had different, complementary face processing deficits, which would be predicted if there were hemispheric lateralization of different face perceptual functions. We tested three patients with pure alexia from left fusiform lesions and one prosopagnosic subject with a right fusiform lesion. First, they had standard neuropsychologic tests of face identity recognition. Second, we atested their ability to discriminate faces in images reduced to high-contrast linear contours, similar to letters. Third, we assessed their ability to detect and discriminate facial speech patterns, and to identify these and integrate them with speech sounds in the McGurk effect (Campbell et al, 1986). Alexic subjects had normal familiarity for face identity on the Cambridge Face Memory Test. However, they were impaired in matching faces for identity across viewpoint, which was worse with line-contour faces. The prosopagnosic patient was also impaired in matching faces across viewpoints, but did well with line-contour faces. Alexic patients could detect facial speech patterns but had trouble identifying them and integrating them with speech sounds, whereas identification and integration was intact in the prosopagnosic subject. We conclude that, in addition to visual word processing, the left fusiform gyrus is involved in processing linear contour information and speech patterns in faces, a contribution complementary to the face identity processing of the right fusiform gyrus.

Object Recognition: Neural mechanisms

Saturday, May 20, 10:45 am - 12:30 pm
Talk Session, Talk Room 1
Moderator: Timothy Andrews

22.11, *10:45 am* **Dynamic differences in letter contrast polarity improve peripheral letter string and word recognition performance** Jean-Baptiste Bernard[1,2,3,4](jean-baptiste.bernard@univ-amu.fr), Eric Castet[1,2]; [1]Laboratoire de Psychologie Cognitive, CNRS, UMR 7290, [2]Aix-Marseille Université, [3]Fondation de l'avenir, [4]Fondation Visaudio

Letter crowding (the inability to identify a letter when surrounded by other letters) is reduced when target and flankers are dissimilar. This release is particularly strong when target and flankers have different contrast polarities (Kooi et al, 1994), but peripheral word recognition does not benefit from this release because observers need to simultaneously report target and flankers of different contrasts (Chung et al, 2010). Here, we investigate if the sequential uncrowding of successive letters using a dynamic contrast polarity difference could improve peripheral letter string and word recognition performance. Three subjects participated in two experiments with letters presented horizontally at 10° in the lower visual field in white or black on a gray background (same absolute contrast value) while eye position was controlled. Subjects identified trigrams (Experiment 1) and 5-letter words (Experiment 2) using three different displays (4 blocks of 50 trials for each experiment and each display): (a) Basic display (Black letters), (b) Static contrast polarity variation (SCPV) display (letters with static alternate contrast polarity) and (c) Dynamic contrast polarity variation (DCPV) display (each letter successively changing from black to white for 200 ms from left to right). Presentation duration was 800 ms in Experiment 1, and depended on subjects in Experiment 2 (3.54±1.26 s). Letter print-size was adjusted so that letter recognition rate was at 50% for the basic display in Experiment 1. For each subject, results for Experiments 1 and 2 show the best recognition rate for the DCPV display (average: 64±4% (Exp1) and 72±5% (Exp2)) compared to the SCPV (40±2% (Exp1) and 57±3% (Exp2)) and basic (42±3% (Exp1) and 49±6% (Exp2)) displays. These results suggest that peripheral letter string and word recognition can be improved using letter contrast polarity differences if word letters are successively uncrowded.

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22.12, *11:00 am* **A developmental deficit in seeing the orientation of typical 2D objects** Gilles Vannuscorps[1](gvannuscorps@fas.harvard.edu), Albert Galaburda[2], Eric Falk[3], Alfonso Caramazza[1,4]; [1]Department of Psychology, Harvard University, Cambridge (MA), USA, [2]Department of Neurology, Harvard Medical School and Beth Israel Deaconess Medical Center, Boston (MA), USA, [3]Carroll School, Lincoln (MA), USA, [4]Center for Mind/Brain Sciences, Università degli Studi di Trento, Trento (TN), Italy

We report the results from a single-case study of an adolescent, Davida, with no remarkable medical history, normal neurological exam, brain MRI and electroencephalogram, who has a highly specific deficit in perceiving the orientation of static, moving, flashed and flickering 2D shapes such as black, grey or colored letters, arrows, abstract shapes and line drawing of objects and faces. Davida reports seeing multiple orientations of these stimuli concurrently (the correct orientation and the equivalent of its rotation by 90, 180 and 270 degrees). Davida's results in non-speeded tasks probing her perception of orientation through verbal judgments, visual illusions, direct copy, and directed movements corroborated this difficulty. For instance, when asked to point to the tip of an arrow shown on a computer screen, she typically pointed where the tip of the arrow would be if the arrow was rotated by 90, 180 or 270 degrees. In contrast, (a) the processing of orientation from auditory, tactile and kinesthetic information is intact; (b) visual judgments about the identity, shape, distance, color, size, movement and location of the same kind of stimuli are intact; and (c) the perception of the orientation of the same shapes (letters, arrows, abstract shapes) shown in 3D, under very low luminance contrast and very low spatial frequencies is intact. The dissociation between processes engaged in the perception of the orientation of 2D shapes under medium to high luminance contrast and spatial frequency from those involved in the perception of the identity, shape, distance, color, size, movement and location of the same kind of stimuli, and those involved in the perception of the orientation of low contrast and low spatial frequency 2D and 3D shapes raises intriguing questions about the interaction of dorsal and ventral visual processes across the two hemispheres.

22.13, *11:15 am* **A data-driven approach to stimulus selection reveals the importance of visual properties in the neural representation of objects.** David Coggan[1](ddc506@york.ac.uk), David Watson[1], Tom Hartley[1], Daniel Baker[1], Timothy Andrews[1]; [1]Department of Psychology, University of York, UK

The neural representation of objects in the ventral visual pathway has been linked to high-level properties of the stimulus, such as semantic or categorical information. However, the extent to which patterns of neural response in these regions reflect more basic underlying principles is unclear. One problem is that existing studies generally employ stimulus conditions chosen by the experimenter, potentially obscuring the contribution of more basic stimulus dimensions. To address this issue, we used a data-driven analysis to describe a large database of objects in terms of their visual properties (spatial frequency, orientation, location). Clustering algorithms were then used to select images from distinct regions of this feature space. Images in each cluster did not clearly correspond to typical object categories. Nevertheless, they elicited distinct patterns of response in the ventral stream. Moreover, the similarity of the neural response across different clusters could be predicted by the similarity in image properties, but not by the similarity in semantic properties. These findings provide an image-based explanation for the emergence of higher-level representations of objects in the ventral visual pathway.

22.14, *11:30 am* **Neural Mechanisms of Categorical Perception in Human Visual Cortex** Edward Ester[1](edward.ester01@gmail.com), Thomas Sprague[1,2], John Serences[1,2]; [1]Department of Psychology, University of California, San Diego, [2]Neurosciences Graduate Program, University of California, San Diego

Category learning warps perceptual space by enhancing the discriminability of physically similar exemplars from different categories and minimizing differences between equally similar exemplars from the same category, but the neural mechanisms responsible for these changes are unknown. One possibility is that categorization alters how visual information is represented by sensory neural populations. Here, we used a combination of fMRI, EEG, and computational modeling to test this possibility. In Experiment 1, we used fMRI and an inverted encoding model (IEM) to estimate population-level feature representations while participants classified a set of orientations into two discrete groups (Freedman & Assad, 2006). We reasoned that if category learning alters representations of sensory information, then orientation-selective responses in early visual areas should be biased according to category membership. Indeed, representations of orientation in visual areas V1-V3 were biased away from the actual stimulus orientation and towards the center of the appropriate category. These biases predicted participants' behavioral choices and their magnitudes scaled inversely with the angular distance separating a specific orientation from the category boundary (i.e., larger biases were observed for orientations adjacent to the boundary relative orientations those further away from the boundary). In Experiment 2, we recorded EEG over occipitoparietal electrode sites while participants performed a similar categorization task. This allowed us to generate time-resolved representations of orientation and track the temporal dynamics of category biases. We observed biases as early as 50-100 ms after stimulus onset, suggesting that category learning alters how visual information is represented by sensory neural populations.

Acknowledgement: NIH R01-EY025872

22.15, *11:45 am* **Joint coding of shape and blur in area V4** Timothy Oleskiw[1,2](oleskiw@uw.edu), Amy Nowack[2], Anitha Pasupathy[2]; [1]Department of Applied Mathematics, University of Washington, [2]Department of Biological Structure, University of Washington

Blur is a common and informative cue of naturalistic visual scenes. For example, cast shadows have blurry boundaries, as do objects outside the focal plane, and surface features of 3D objects may be associated with shading blur. Interestingly, while psychophysical studies have long demonstrated the importance of detecting and encoding blur for scene segmentation and perception of depth and 3D structure, the underlying neural mechanisms have yet to be discovered. To investigate this we record single-unit activity from area V4 in two awake fixating Macaca mulatta in response to shape stimuli exhibiting blurred boundaries. Specifically, after classifying shape selectivity of single neurons, preferred and non-preferred shapes are presented under multiple levels of Gaussian blur. Surprisingly, our data reveals a population of V4 neurons which are tuned for intermediate levels of boundary blur, demonstrating, for the very first time, blur selectivity anywhere in primate visual cortex. After performing a series of control experiments our results reveal a sophisticated neural computation within V4, with responses being enhanced by the removal of high spatial frequency content; this effect is not explained by confounding factors of stimulus size, curvature, or contrast. We interpret our findings in the context of computational studies that argue for shape and blur as forming a sufficient representation of naturalistic images. A simple descriptive model is proposed to explain observed data, wherein blur selectivity modulates the gain of shape-selective responses, supporting the hypothesis that shape and blur are fundamental features of a sufficient neural code for natural image representation within the ventral pathway. More generally, we believe that our findings will shift paradigms surrounding area V4's role in visual processing: as opposed to computations of object recognition alone, our results suggest that V4 also provides the neural substrate underlying processes of scene segmentation and understanding.

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22.16, *12:00 pm* **Selective attention modulates face categorization differently in the left and right hemispheres** Genevieve Quek[1](genevieve.lauren.quek@gmail.com), Dan Nemrodov[2], Bruno Rossion[1], Joan Liu-Shuang[1]; [1]Psychological Sciences Research Institute and Institute of Neuroscience, University of Louvain, Belgium, [2]Department of Psychology, University of Toronto Scarborough, Canada

Despite the broad interest in the role of selective attention in human face perception, there has been little focus on characterizing attentional modulation of this critical brain function in a dynamic visual environment. Here we exploited fast periodic visual stimulation to separately characterise the impact of attentional enhancement and suppression on generic face categorization. We recorded 128 channel EEG while participants viewed a 6Hz stream of object images (e.g., buildings, animals, objects, etc.) with a face image embedded as every 5th image in the sequence (i.e., OOOOFOOOOFOOOOF…). Stimulating the visual system this way elicits a response at exactly 6Hz, reflecting processing common to both face and object images, and a response at 6Hz/5 (i.e., 1.2 Hz), reflecting a differential response to faces as compared to objects. We measured this face-selective response while manipulating the focus of task-based attention: On Attend Faces trials, participants responded to instances of female faces in the sequence; on Attend Objects trials, they responded to instances of guitars, and on Baseline trials, they performed an orthogonal task, monitoring a central fixation cross for colour changes. We inspected indices of attentional enhancement (Attend Face–Baseline) and attentional suppression (Baseline–Attend Objects) on right and left occipito-temporal electrodes separately. We observed that during the orthogonal task, face-specific activity was predominantly centred over the occipito-temporal region of the face-preferred hemisphere (right hemisphere in 13/15 observers). Where task-based attentional suppression was comparable across the left and right hemispheres, task-based attentional enhancement was much more prominent in the non face-preferred hemisphere (left hemisphere in 13/15 observers). These results suggest the left and right face-selective cortical regions may support face categorization in distinct ways – where the face-preferred hemisphere (typically right) may be mandatorily engaged by faces, the non face-preferred hemisphere (typically left) may be flexibly recruited to serve current tasks demands.

22.17, *12:15 pm* **Does symmetry have a special status in single neurons?** RT Pramod[1,2](pramodrt@ece.iisc.ernet.in), SP Arun[1,2]; [1]Center for Neuroscience, Indian Institute of Science, Bangalore, India, [2]Department of Electrical Communication Engineering, Indian Institute of Science, Bangalore, India

Symmetry is a salient global attribute: it is easy to detect, remember and influences fundamental visual processes such as recognition and segmentation. Yet we know very little about how symmetry is represented in neurons. To address this issue, we recorded from single neurons in the monkey inferior temporal (IT) cortex using shapes made of two arbitrary parts connected by a stem. Shapes made with two identical parts were symmetric while those with different parts were asymmetric. We tested the same shapes oriented vertically and horizontally to characterize mirror symmetry about both axes. Using these shapes we asked whether symmetric objects had any special status at the neural level that would explain their special status at the behavioural level. Our main findings were similar for horizontal and vertical objects: (1) Symmetric objects did not evoke significantly stronger neural responses compared to asymmetric objects; (2) Neural responses to the whole object were explained as a linear sum of the part responses, with no special deviation for symmetric objects; (3) Neural responses to symmetric objects elicited no greater nonlinear interactions between parts compared to asymmetric objects and (4) The sole distinguishing characteristic of symmetric objects was that they were more distinct from each other compared to equivalent asymmetric objects. This distinctiveness is a straightforward outcome of part summation but explain a number of observations regarding symmetry in perception. We propose that symmetry becomes special in perception due to generic computations at the neural level.

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Perceptual Learning

Saturday, May 20, 10:45 am - 12:30 pm
Talk Session, Talk Room 2
Moderator: Jozsef Fiser

22.21, *10:45 am* **REM sleep stabilizes visual perceptual learning which was rendered fragile by NREM sleep** Yuka Sasaki[1](yuka_sasaki@brown.edu), Masako Tamaki[1], Takeo Watanabe[1]; [1]Brown University, Department of Cognitive, Linguistic, and Psychological Sciences

NREM sleep play roles in enhancing visual perceptual learning (VPL). However, to successfully consolidate already enhanced VPL, a stabilization process of VPL needs to occur after the enhancement. Otherwise, VPL should be left fragile and vulnerable to interference by training of another task. Since REM sleep succeeds NREM sleep during which VPL is enhanced, we tested whether REM sleep plays a role in stabilization. More specifically, we tested whether VPL is still resilient to interference and therefore is stabilized if REM sleep does not occur after training. We used a two-block training paradigm using the texture discrimination task. Earlier studies have shown that learning of the first training with a stimulus is interfered by the second training with a similar but different stimulus unless the time-interval between the two trainings was longer than 60 min. Here, we separated two trainings by a 120-min interval, during which subjects either slept (sleep group, n=11) or stayed awake (control-wake group, n=10). Performance was measured before and after the first training, before the interval, and after the second training. In the control-wake group, consistently with the previous findings, the first learning was not interfered by the second, which showed stabilization of the first learning during wakefulness occurred. In the sleep group, the first learning was significantly interfered by the second training with subjects who showed only NREM sleep, whereas no such interference occurred with subjects who showed REM sleep after NREM sleep. The degree of the resilience of the first learning measured after the second training was significantly correlated with the strength of theta activity (5-7 Hz) from the visual areas retinotopically corresponding to the trained visual field during REM sleep. These results suggest that theta activity in the visual area during REM sleep is necessary for consolidation of VPL during sleep after training.

Acknowledgement: NIH R01EY019466, NSF BCS 1539717

22.22, *11:00 am* Evidence for awake replay in human visual cortex after training

Ji Won Bang[1](kirstens03@gmail.com), Yuka Sasaki[2], Takeo Watanabe[2], Dobromir Rahnev[1]; [1]School of Psychology, Georgia Institute of Technology, [2]Cognitive, Linguistic & Psychological Sciences, Brown University

Understanding how the human brain learns is a fundamental goal of neuroscience. A large body of animal research shows that awake replay -- the repetition of neuronal patterns exhibited during learning -- plays a critical role in memory formation. However, very few studies have tested whether awake replay occurs in humans and none have employed non-hippocampus-dependent tasks. Here, we examined whether awake replay occurs in the human visual cortex immediately after extensive training on a visual task. We trained participants on one of two Gabor patch orientations (45° vs. 135°) using a two-interval forced choice (2IFC) detection task. Critically, using functional MRI, we obtained participants' spontaneous brain activity both before and after the vision training. We then tested whether the post-training spontaneous activity in early visual cortex appeared more similar to the trained than untrained stimulus (to classify the spontaneous activity we first constructed a decoder that could distinguish the patterns of activity for each Gabor orientation). Consistent with the existence of awake replay, we found that immediately after vision training, the activation patterns in areas V1 and V3 were more likely to be classified as the trained orientation. No such difference was found for the pre-training spontaneous activity. In addition, behavioral performance on the trained orientation significantly improved after training demonstrating the effectiveness of the training. Taken together, these results demonstrate that a process of awake replay occurs immediately after visual learning. Our findings are the first to demonstrate the phenomenon of awake replay in non-hippocampus-dependent tasks. We speculate that awake replay may be fundamental to all types of learning.

22.23, *11:15 am* Combining the cholinesterase inhibitor donepezil with perceptual learning in adults with amblyopia

Susana Chung[1,2,3](s.chung@berkeley.edu), Roger Li[1,2,3], Michael Silver[1,2,3], Dennis Levi[1,2,3]; [1]School of Optometry, UC Berkeley, [2]Vision Science Graduate Program, UC Berkeley, [3]Helen Wills Neuroscience Institute, UC Berkeley

Amblyopia is a developmental disorder that results in a wide range of visual deficits. Although brain plasticity is limited in adults, one approach to recovering vision in adults with amblyopia is perceptual learning (PL). Recent evidence suggests that neuromodulators may enhance adult plasticity. Here we asked whether donepezil, a cholinesterase inhibitor, can enhance PL in adults with amblyopia. Nine adults with amblyopia were first trained on a single-letter identification task (letters were presented at low contrast) while taking a daily dose (5 mg) of donepezil throughout training. Following 10,000 trials of training, participants showed improved contrast sensitivity in identifying single letters. However, the magnitude of improvement was no greater than, and the rate of improvement was slower than that obtained in a previous study in which adults with amblyopia were trained using identical experimental protocols but without donepezil (Chung, Li & Levi, 2012). In addition, the transfer of learning to a size-limited (acuity) or to a spacing-limited (crowding) task was less than that found in the previous study with no donepezil administration. After an interval of several weeks, six of these participants returned for a second training task — flanked letter identification (identifying crowded letters) — also with concurrent donepezil administration. Following another 10,000 trials of training, only one observer showed learning for this subsequent training task, which has been previously shown to be highly amenable to PL in adults with amblyopia. Control studies showed that the lack of a learning effect on the flanked letter identification task was not due to either the order of the two training tasks or the use of a sequential training paradigm. Our results reveal that donepezil does not enhance or speed up PL of single-letter identification in adults with amblyopia, and importantly, may even block participants' PL of a task related to crowding.

Acknowledgement: NIH/NEI Research Grants R01-EY012810 and R01-EY020976

22.24, *11:30 am* Dissociable effects of stimulus strength, task demands, and training on occipital and parietal EEG signals during perceptual decision-making

Sirawaj Itthipuripat[1](itthipuripat.sirawaj@gmail.com), Kai-Yu Chang[2], Vy Vo[1], Stephanie Nelli[1], John Serences[1,3]; [1]Neurosciences Graduate Program, UCSD, [2]Cognitive Science, UCSD, [3]Psychology, UCSD

In most tasks, behavioral performance depends on several factors including stimulus strength, task demands, and also the amount of expertise. Here, we investigated how these different factors impacted neural modulations of early sensory and post-sensory processing. To address this question, we recorded encephalography (EEG) from human subjects performing a perceptual decision-making task and used two event-related potentials (ERPs): an early visual negativity (VN) and a late centro-parietal positivity (CPP) as neuromarkers for early sensory and post-sensory processing, respectively. Across four days, subjects discriminated the orientation of a patch of oriented lines as we manipulated stimulus strength (0-60% coherence) and task demands (number of possible target orientations: 2 or 4 choices). While behavioral performance improved with increased stimulus coherence, reduced choice number, and increased training duration, we observed distinguishable modulations of the VN and CPP components. Specifically, the amplitudes of the VN and CPP increased multiplicatively with increased stimulus coherence. On the other hand, reducing the task demands did not alter the VN amplitude, but increased the ramping rate of the CPP. Similar to increasing stimulus coherence, training amplified the VN amplitude, however; it reduced the CPP amplitude. The data suggest that altering task demands can produce an effect on post-sensory processing that is similar to changing stimulus strength but in the absence of changes in early sensory processing. On the other hand, training and increasing stimulus strength can produce similar effects on early sensory processing with different patterns of neural modulations at post-sensory stages.

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22.25, *11:45 am* Double training reduces motor response specificity

Lukasz Grzeczkowski[1,2](lukasz.grzeczkowski@epfl.ch), Aline Cretenoud[1], Fred Mast[3], Michael Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), [2]Department of Psychology, Ludwig-Maximilian University of Munich, [3]Institute of Psychology, University of Bern

The hallmark of perceptual learning is its specificity. Recently, we trained observers with a classical three-line bisection task where observers responded by button presses whether the central line is offset to the left or right. Performance improved. However, there was no transfer to the same bisection task when observers adjusted the central line with the computer mouse. Likewise, adjustment training did not transfer to the button press condition. Here, we first show that training is even specific when the trained hand is used for both motor responses. However, there is transfer from the trained to the untrained hand. Most importantly, we show that a double training protocol enables strong transfer from the mouse adjustment condition to the button presses condition but not the other way around. In each training session, observers trained blockwise with either a vertical bisection stimulus and adjusted the central line with the computer mouse or they trained with a horizontal bisection stimulus and responded by button presses. Before and after training, we tested performance with the vertical bisection stimulus where observers responded by button presses. Surprisingly, training led to transfer in this condition. Without the double training, there was no such transfer. We propose that stimuli are coded together with their corresponding actions when both are linked through extensive learning.

Acknowledgement: Project "Learning from Delayed and Sparse Feedback" (Project Number: CRSII2_147636) of the Swiss National Science Foundation (SNFS)

22.26, *12:00 pm* Visual statistical learning provides scaffolding for emerging object representations

Jozsef Fiser[1](fiserj@ceu.edu), Gabor Lengyel[1], Marton Nagy[1]; [1]Department of Cognitive Science, Central European University, Hungary

Although an abundance of studies demonstrated human's abilities for visual statistical learning (VSL), much fewer studies focused on the consequences of VSL. Recent papers reported that attention is biased toward detected statistical regularities, but this observation was restricted to spa-

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tial locations and provided no functional interpretation of the phenomenon. We tested the idea that statistical regularities identified by VSL constrain subsequent visual processing by coercing further processing to be compatible with those regularities. Our paradigm used the well-documented fact that within-object processing has an advantage over across-object processing. We combined the standard VSL paradigm with a visual search task in order to assess whether participants detect a target better within a statistical chunk than across chunks. Participants (N=11) viewed 4-4 alternating blocks of "observation" and "search" trials. In both blocks, complex multi-shape visual scenes were presented, which unbeknownst to the participants, were built from pairs of abstract shapes without any clear segmentation cues. Thus, the visual chunks (pairs of shapes) generating the scenes could only be extracted by tracking the statistical contingencies of shapes across scenes. During "observation", participants just passively observed the visual scenes, while during "search", they performed a 3-AFC task deciding whether T letters appearing in the middle of the shapes formed a horizontal or vertical pairs. Despite identical distance between the target letters, participants performed significantly better in trials in which targets appeared within a visual chunk than across two chunks or across a chunk and a single shape. These results suggest that similar to object-defined within/between relations, statistical contingencies learned implicitly by VSL facilitate visual processing of elements that belong to the same statistical chunk. This similarity between the effects of true objects and statistical chunks support the notion that VSL has a central role in the emergence of internal object representations.

22.27, *12:15 pm* **Evidence for stimulus abstraction before perceptual learning** Xin-Yu Xie[1](xiexy518@pku.edu.cn), Cong Yu[1]; [1]School of Psychological and Cognitive Sciences, IDG-McGovern Institute for Brain Sciences, and Peking-Tsinghua Center for Life Sciences, Peking University, Beijing

Visual perceptual learning (VPL) is traditionally attributed to early cortical neural plasticity or response reweighting. However, our double training studies demonstrate often complete learning transfer to untrained locations, orientations, and physical stimuli, suggesting that VPL involves learning at a conceptual level (e.g., learning an abstract orientation concept). It is unclear whether such a concept is abstracted after learning (e.g., abstracting the rules of reweighting that define a concept), or before learning (e.g., abstracting stimulus information before reweighting). Subjects practiced orientation discrimination with a Gabor that either rotated trial-by-trial in 12 locations (anti-clockwise) and 4 orientations (clockwise) at 5-deg eccentricity, or in a roving order (47 conditions excluding the pre/post one that was never practiced). Each condition received 2 trials per block, 12 trials per session, over 5 daily sessions. A staircase controlled the orientation difference from trial to trial. The multiple stimulus conditions and scarce number of trials per condition minimize the possibility of early cortical plasticity and response reweighting (and so abstraction of reweighting rules). Both rotating and roving training conditions produced significant orientation learning. Training also improved the untrained pre/post condition, as much as when training was performed at the pre/post condition with equal number of trials. Similar effects were seen with orientation training using symmetry dot-patterns whose global orientation rotated. However, training with an irrelevant contrast discrimination task with multiple conditions had no significant effect on orientation performance at the pre/post condition, indicating that orientation learning is genuine and not caused by improved attention to the periphery. These results suggest that early cortical plasticity and response reweighting, as well as abstraction of reweighting rules, are unnecessary for VPL. Instead the brain may abstract the stimulus information in advance before reweighting, which explains VPL and its transfer in various double training studies and in current multiple-condition training study.

Acknowledgement: Supported by a Natural Science Foundation of China grant (31230030)

Saturday AM

SATURDAY MORNING POSTERS

ATTENTION: FEATURES

Saturday, May 20, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

23.3001 Acts feature based suppression of ignored stimuli globally or locally in the visual field?

Matthias Mueller[1](m.mueller@uni-leipzig.de); [1]Dept. of Psychology, University of Leipzig, Germany

A key property of feature-based attention is global facilitation of the attended feature throughout the visual field. However, the question to what extend suppression of unattended features acts globally as well is still a matter of controversial results. We presented superimposed randomly moving red and blue dot kinematograms (RDKs) flickering at a different frequency each to elicit frequency specific steady-state visual evoked potentials (SSVEP) in the center of the screen and a red and blue RDK in the left and right periphery, respectively. Subjects shifted attention to one color of the superimposed central RDKs to detect coherent motion events in the attended color RDK, while the peripheral RDKs were task irrelevant. We found global facilitation of the attended color but suppression was restricted to the location of focused attention. We replicated our previous result: shifting of processing resources followed a bi-phasic process with a leading enhancement of the attended RDK followed by suppression of the unattended RDK. Our results are based on a pre-cue baseline serving as reference for post-cue SSVEP analysis. Other reference measures, like a neutral color (Painter et al., 2014), probe stimuli (Moher et al., 2014; Zhang and Luck, 2009), or no baseline reference (Störmer and Alvarez, 2014) resulted in a different pattern of effects. While some results suggested global suppression relative to the reference measure, others suggest local suppression, hampering conceptual advancement. Thus, providing solutions for a common and unique reference frame seems to be an important challenge for future studies to uncover neural dynamics in visual attention in general.

Acknowledgement: German Research Foundation

23.3002 Using Angles as Features

Matthew Inverso[1](minverso@uci.edu), Charles Chubb[1], Charles Wright[1], George Sperling[1]; [1]University of California, Irvine

Introduction. What properties of angles can serve as features for spatially distributed attention? Here we use the centroid paradigm to investigate this question. Methods. Stimuli were clouds of randomly oriented v's with vertices of different angles. In Experiment 1, stimuli comprised eight v's, 4 each with acute and obtuse angles of size that varied randomly both within a trial and across trials. Stimuli were exposed for 200 ms and followed by noise masks. In separate conditions, observers strove to mouse-click the centroid of the v's, giving equal weight to (1) all angles, (2) acute angles (< 90 deg) while ignoring obtuse angles (>90 deg), (3) obtuse angles while ignoring acute angles. Experiments 2 and 3 used v's with only two fixed angle sizes, and participants strove to mouse-click the centroid of a designated one of the two sets. Results. Participants in Experiment 1 gave about 4-5 times more average weight to targets than distracters (we call this measure "Selectivity"). However, for component angles of 67.5 versus 112.5 deg, the most similar target and distracter angles, selectivity was only about 2.5. In Experiment 2, when filtering between just two acute angles (30, 60 deg) participants gave target acute angles about 4 times more weight than distractors. However, when discriminating between 75 versus 105 or between 120 versus 150 deg, selectivity was reduced to less than 2. Conclusions. Angles can be used as a feature in feature based attention. For equal angular differences between targets and distracters, selectivity is greater for small than for large angles.

23.3003 Feature-based surround suppression in the motion domain

Sang-Ah Yoo[1, 5](sangahy@yorku.ca), John Tsotsos[2, 5], Mazyar Fallah[3, 4, 5]; [1]Department of Psychology, York University, [2]Department of Electrical Engineering and Computer Science, York University, [3]School of Kinesiology and Health Science, York University, [4]Canadian Action and Perception Network, York University, [5]Centre for Vision Research, York University

When we attend to a certain visual feature, such as a specific orientation (Tombu & Tsotsos, 2008) or specific colour (Störmer & Alvarez, 2014), processing of features nearby in that space are suppressed (i.e., feature-based surround suppression). In the present study, we investigated feature-based surround suppression in a new feature domain, motion direction, using motion repulsion as a measurement. Chen and colleagues (2005) suggested that attention to one motion direction reduces motion repulsion by inhibiting the other direction. Based on this finding, we conducted a similar direction judgment task having naïve participants. They reported perceived directions of two superimposed motions after viewing the motions for 2 sec. The directional differences between two motions systematically varied (10~70 deg) and the surfaces were separated by different colours (green or red). In the unattended condition, participants performed direction judgment tasks only, attending equally to both motions. In the attended condition, a colour cue was presented, indicating which motion participants should attend. Participants were asked to detect a brief directional shift of the cued motion and then, report the perceived motion directions. We compared the magnitude of motion repulsion between the two attention conditions. In contrast to the findings of Chen and colleagues, participants showed greater motion repulsion in the attended condition than in the unattended condition, especially when two motions moved along nearby directions. The results suggest that feature-based surround suppression exists in the motion domain and that it may occur on an early stage of motion processing where the global direction of motion is computed.

Acknowledgement: the Canada Research Chairs Program, the Natural Sciences and Engineering Research Council of Canada, and the Air Force Office for Scientific Research (USA)

23.3004 Does Feature-Based Attention for Grayscale Vary Across Visual Tasks with Identical Stimuli?

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Are feature-based visual attention filters for dark versus light items invariant across different tasks? Method. Stimuli were briefly flashed (300 ms) clouds comprising 16 bars (length, width = .72°, .045°), two each of 8 Weber contrasts ±0.25, ±0.5, ±0.75, ±1 on a mean gray background. Bar orientations had a fixed dispersion of 22.5 deg. around a mean that varied randomly across trials. In the centroid task, the participant strove to mouse-click the centroid of a "target set" of bars, giving equal weight to all bars in this set while ignoring all the other "distractor" bars. In the slant task, participants adjusted the orientation of a central response bar to match the mean-orientation of the bars in the target set, giving equal weight to all target bars while ignoring the distractor bars. In each of the two tasks, in separately blocked conditions, the target set included 1) all bars, 2) bright bars only [bars more luminous than the background] or 3) dark bars only. Results. In each condition in each task, we derived an attention filter that reflected the impact exerted on the participant's responses by bars of different Weber contrasts. In both tasks, participants' attention filters in the all-bars condition gave nearly equal weight to all 8 Weber contrasts. In the bright-bars-only and dark-bars-only selective attention conditions, participants' centroid-task attention filters more accurately approximated equal weight to all target bar luminances than slant-task filters, which despite contrary instructions and feedback, weighted bars more nearly in proportion to absolute Weber contrast. On the other hand, in selective attention to bright-bars-only and dark-bars-only conditions, slant-task filters assigned very little weight to distractors yielding excellent target-to-distractor-weight ratios: >14:1, whereas centroid-task filters were less selective, yielding target-to-distractor-weight ratios: 5:1. Conclusion. Attention filters for gray-scale can differ between different tasks using identical stimuli.

23.3005 Shape interactions require more than feedforward representation

Larissa D'Abreu[1](larissa.dabreu@du.edu), Timothy Sweeny[1]; [1]University of Denver

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At any moment, some objects in the environment are seen clearly whereas others elude visual awareness. Objects that go unseen may be missed because they fail to engage reentrant processing from higher- to lower-levels of visual analysis. Nevertheless, several investigations suggest that these unseen objects are processed, at least to some extent, in a feedforward wave of representation, and that this processing can influence attention and even bias other perceptual judgments. Here, we attempted to understand the depth of feedforward representation at an intermediate level of visual analysis. Object-substitution masking (OSM) is thought to prevent feedback activity while preserving feedforward activity. Thus, we used OSM to evaluate whether the feedforward representation of an unseen shape's aspect ratio is potent enough to influence the appearance of another nearby shape that is clearly visible. Observers viewed two simultaneously presented ellipses on each trial for 17msec. An arrow appeared after the ellipses disappeared, cueing observers to rate the aspect ratio (e.g. how tall or flat, using a magnitude matching screen) of one ellipse from the pair. On some trials, the uncued ellipse was masked by four adjacent dots that lingered after its offset for 240 msec. On each trial, we measured subjective awareness by asking observers how many ellipses they saw clearly. As expected, the aspect ratio of the cued ellipse was biased toward that of the uncued ellipse on control trials with no masking—perceptual averaging. Crucially, this averaging effect did not occur when the uncued ellipse was successfully masked. Interestingly, when observers indicated that they saw both ellipses, we found a significant effect of perceptual averaging intermediate between the other conditions. These results suggest that feedforward representation of an unseen object is insufficient to influence the perception of a nearby object, at least at intermediate levels of visual analysis.

23.3006 **Variable Viewpoint Hybrid Search: Searching for the Object or the Image?** Abla Alaoui Soce[1](aalaouisoce@partners.org), Bochao Zou[1,3], Jeremy Wolfe[1,2]; [1]Brigham and Women's Hospital, [2]Harvard Medical School, [3]School of Optoelectronics, Beijing Institute of Technology

In hybrid search, observers search visual arrays for any of several target types held in memory. Items in the visual display must be matched to some internal representation or 'template'. Previous experiments have shown that searching for specific targets is more efficient than searching for categories of targets (Cunningham & Wolfe, 2014). Between search for this exact image of this exact chair and search for the category "chairs", is search for a specific object that can be viewed from multiple positions. Such search for targets that appear under different viewpoints is closer to real world search. We conducted a hybrid search experiment using specific target objects that could be rendered in multiple viewpoints. We compare this varied viewpoint condition to a specific viewpoint condition, in which each target appeared in only a single viewpoint. Is varied viewpoint hybrid search similar to single viewpoint search, suggesting that search templates are independent of viewpoint? Or, is varied viewpoint search like a category search where multiple views are like multiple instances of a category? When the memory set size is 2-4, searching for varied viewpoint targets (2 targets: 33 msec/item; 4 targets: 82 msec/item) was just as fast as searching for single viewpoint targets (2 targets: 38 msec/item; 4 targets: 69 msec/item), ($t(11)=0.88$, $p=0.40$; $t(11)=1.09$, $p=0.30$). However, when more targets (8-16) are stored in memory, searching for varied viewpoint targets (8 targets: 127 msec/item; 16 targets: 150 msec/item) was less efficient than searching for specific viewpoints (8 targets: 80 msec/item; 16 targets: 103 msec/item) ($t(11)=4.63$, $p< 0.001$, $t(11)=3.36$, $p< 0.01$), more closely resembling a categorical search (8 targets: 125 msec/item). This suggests that a small number of viewpoint independent representations can be activated in hybrid search. For larger memory sets, however, observers might only activate a canonical view, making search harder for other views.

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23.3007 **How does attention alter perceived contrast? Enhancement at low contrast levels turns into attenuation at high contrast levels.** Liu-Fang Zhou[1,2](liufangpsy@gmail.com), Simona Buetti[2], Shena Lu[1], Yong-Chun Cai[1]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University, Hangzhou, China, [2]Department of Psychology, University of Illinois at Urbana-Champaign, IL, USA

It has been a long-standing question of whether attention alters appearance. A recent landmark study demonstrated that attention enhances apparent contrast (Carrasco, Ling, & Read, 2004, Nature Neuroscience). One shortcoming of the tasks used in this type of study is that they are prone to induce cue-related response biases. Here we used two opposite tasks to isolate the response bias in these tasks. Participants were presented with an abrupt cue and two gratings afterward, and were instructed to report the orientation of the stimulus which looked higher (Experiment 1) or lower (Experiment 2) in contrast. By comparing performance across experiments, the reversal of instructions allows to better estimate the magnitude of observed response biases and therefore to better isolate the effects of attention on apparent contrast. We also systematically study attentional effects over a wide range of contrast levels (15-60%). When using a higher comparative task, we found a boost of apparent contrast by attention with low-contrast stimuli (15% and 25%), but null effects with high-contrast stimuli (40% and 60%). When using a lower comparative task, surprisingly, an attentional attenuation of apparent contrast was found at high contrast levels, whereas no effect was found at low contrast levels. Thebetween-experiment analysis demonstrated that the observed effect was an addictive combination of a perceptual effect induced by attention and response bias to report the item on the side where the cue was presented. After isolating the two effects, we were able todemonstrate that attention alters perceived contrast in a contrast-dependent way: attention enhances contrast at low contrast levels, but attenuates it at high contrast levels.

Acknowledgement: Zhejiang ProvincialNatural Science Foundation of China (LY13C090001)

23.3008 **Surround Suppression in Feature-based Attention to Color** Wanghaoming Fang[1](fangwan1@msu.edu), Mark Becker[1], Taosheng Liu[1,2]; [1]Department of Psychology, Michigan State University, [2]Neuroscience Program, Michigan State University

Goal. Feature-based attention can enhance perception to an attended color. However, it is less clear how attending to a color modulates processing of nearby colors. The feature-similarity gain model predicts a graded level of attentional enhancement centered on the attended color. However, a center-surround mechanism claims inhibition of colors nearby the attended one (Stormer & Alvarez, 2014). Here, we investigate how attentional modulation varies systematically as a function of the difference between the stimulus color and the attended color.   Methods. Subjects were sequentially presented with two intervals, with each interval consisting of a patch of static colored dots. In one patch all dots had random colors, while in the other patch one color was overrepresented (the target). Subjects performed a 2IFC task reporting the interval that contained the target. The amount of overrepresentation was determined by interleaved staircases for each target color and each subject in a thresholding session at the start of the experiment. In the cueing condition, a fixed-color cue appeared briefly at the beginning of each trial. The target matched this color on 50% of trials. In the remaining trials, the target was ±15°, ±30°, ±45° or ±60° away from the cued color (6.25% each) on a color wheel (CIE L*a*b space). In separate blocks of neutral trials, there were no cues. The cueing effect was the difference between the neutral and cued conditions for a given color.   Results. For most subjects, we found a significant enhancement for the cued target color and, more importantly, a general trend for inhibition at its immediate neighbors (±15°). Once outside this inhibitory zone, there was a rebound of cueing effect. Thus, our data are consistent with a surround-suppression effect in feature-based attention. We also found evidence for an interaction between attentional modulation and category boundaries in the color space.

Acknowledgement: National Institutes of Health (R01EY022727)

23.3009 **Continuous vs. categorical representation of feature-based attentional priority in human frontoparietal cortex** Mengyuan Gong[1,2](gongmy@msu.edu), Taosheng Liu[1,2]; [1]Department of Psychology, Michigan State University, [2]Neuroscience Program, Michigan State University

Previous studies suggest a functional role of dorsal frontoparietal network in representing feature-based attentional priority, yet how these features are represented remains unclear. In an fMRI experiment, we used a feature cueing paradigm to assess whether attentional priority signals vary continuously or categorically as a function of feature similarity. We presented two superimposed dot fields moving along two linear directions (left-tilted and right-tilted), while varying the angular separation between the two motion directions. Subjects were cued to attend to one of the two dot fields and respond to a possible speed-up in the cued direction. We examined

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how information contained in the multi-voxel neural patterns changed with the angular separation between the two directions. If attentional priority represents continuous changes of the features, priority signals in the dorsal pathway should become more similar when the angular separation between the attended directions decreases. However, if attentional priority represents attended feature in a categorical manner, then priority signals should remain largely invariant with respect to changes in the angular separation. We trained a classifier to decode the attended direction (left-tilted vs. right-tilted) for each angular separation, and found that the decoding accuracy improved with increasing angular separation in the visual cortex (V1 and V2). In contrast, decoding accuracy remained invariant to the degree of feature similarity (and significantly above chance) in the intraparietal sulcus (IPS) and frontal areas (FEF and IFJ). These results indicate dissociated roles of visual cortex and frontoparietal areas in representing attentional priority, suggesting a flexible transformation of feature-based priority from continuous to categorical representation along the dorsal visual streams.

Acknowledgement: National Institutes of Health (R01EY022727)

23.3010 Tuning attention to relative features results in feature-based enhancement and suppression

Josef Schoenhammer[1](josef.schoenhammer@unige.ch), Stefanie Becker[2], Dirk Kerzel[1]; [1]University of Geneva, [2]The University of Queensland

Many theories of visual attention propose that we select sought-for items (targets) by tuning attention to their elementary features (e.g., green, yellow). However, recent findings showed that we often select a target in a context-dependent manner, by tuning attention to its relative features, that is, to the features that the target has relative to the surrounding non-target items (e.g., greener, yellower). In our Experiment 1, we replicated these basic findings, employing a cueing paradigm with spatially unpredictive pre-cues. Target and nontarget colors remained fixed in a block of trials (e.g., yellowish-green and green), so that also the relative color remained constant (e.g., yellower). Consistent with a relational account, we found that the cues elicited cueing effects only when they had the same relative color as the target (e.g., yellowest item), regardless of whether the cues had the same elementary color as the target or not (e.g., yellowish-green or yellow). Critically, cues that mis-matched both, the target's elementary and relative color (e.g., a green cue among yellowish-green contextual cues), elicited inverse cueing effects, that is, slower RTs in cued than uncued trials. It has been hypothesized that these effects might be attributable to suppression of the cue color or, alternatively, to capture by the contextual cues, as those had the same elementary and relative color as the target. In Experiment 2, we added a white cue to each cue array. We assumed that this color would neither be attentionally enhanced nor suppressed. Hence, trials in which white cues preceded at the target location were regarded as baseline. We found that RTs were slower than baseline when the mis-matching cue preceded the target location, but faster than baseline when the matching contextual cues preceded the target location. Thus, the results suggest that inverse effects are the result of combined suppression and enhancement.

23.3011 Short display time reduces distractor interference when distractor is a feature of the target

Zhi Li[1](zli1@zju.edu.cn), Fan Yang[1], Yijie Chen[1]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University

Load theory (Lavie and Tsal, 1994) compromises the long debate of early vs late selection hypothesis of selective attention by assuming that the locus of attentional filter is flexible depending on the perceptual load of the task. The filter operates at an early stage when perceptual load is high and operates at a late stage when perceptual load is low. Evidence supporting load theory often involves a flanker task, in which distractor and target are spatially separated. When distractor and target occupy the same space, however, object-based attention may take over and the distractor may be processed to a late stage regardless of the perceptual load (Chen, 2003; Cosman and Vecera, 2012). The present study examined the load effect when distractor is a feature of the target. Participants judged whether the color of a central item also appeared on the item in a peripheral array. The items were either all colorful numbers or all color squares. The display time of the stimuli was either very short (barely enough for the task) or self terminated (on screen until response). In the colorful number condition, color was task-relevant information and number was task-irrelevant information. By using the results from the color square condition as baseline, the time spent on processing the task-irrelevant feature (i.e. number) in the colorful number condition was calculated. It turned out when the display time was short, less time was spent on processing the task-irrelevant feature than that when the display time was self terminated. These findings showed that the time available for processing the stimuli affected whether the task-irrelevant information would be processed. Short display time significantly reduced the distractor interference even when the distractor was a feature of the target. These findings supported and extended the load theory.

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23.3012 Is Mean Size a Good Example of a Statistical Summary Representation? Centroid versus Mean Size Judgments

Laris RodriguezCintron[1](larisr@uci.edu), Charles Wright[2], Charles Chubb[3]; [1]Cognitive Sciences, University of California Irvine, [2]Cognitive Sciences, University of California Irvine, [3]Cognitive Sciences, University of California Irvine

Introduction. Work by Ariely (2001) inspired interest in research using the judged mean size of a briefly presented set of stimuli, differing in size, as a prototypical example of a statistical summary representation (SSR). Like Ariely, many authors have concluded that mean size judgments rely on a global strategy – i.e., most members of the set are included in this calculation (Ariely, 2001). However, Myczek and Simons (2008) presented simulation results suggesting that mean-size judgments could result from a subsampling strategy. To explore whether subsampling is the appropriate mechanism to explain performance in the mean-size task, we used an efficiency analysis to compare performance across three tasks: two versions of the centroid task and the mean size task. Like the subsampling simulations, the efficiency analysis used in centroid-task research (Sun, Chubb, Wright, Sperling, 2015), is based on the degree that an ideal observer fails to register or include all of the stimuli in the calculation. Method. Observers were presented with a cloud of either 3 or 9 squares for 300 ms followed by a mask. In different sessions, observers were asked to estimate one of (a) the mean size of the stimuli, (b) the centroid of the stimuli ignoring the size differences, or (c) the centroid weighting the elements of the stimuli according to their size. Results. We found that efficiency was high in both centroid tasks, but substantially lower in the mean-size task. Conclusions. These results suggest that stimulus size is registered accurately and can be used effectively in the context of centroid judgments but not for judgments of mean size. Presumably, sources of error other than subsampling lead to the low efficiency observed when judging mean size. Given these results, size judgments may be a poor task to us to study SSRs.

23.3013 Conjunctive targets are better than or equal to both constituent feature targets in the centroid paradigm

A. Nicole Winter[1](wintera@uci.edu), Charles Wright[1], Charles Chubb[1], George Sperling[1]; [1]University of California at Irvine

In the centroid paradigm (Sun, Chubb, Wright, & Sperling, 2015), a method for studying feature-based attention, participants view a brief display of items and then estimate the centroid, or center of mass, of the target items while ignoring the distractors. In our previous work (Winter, Wright, Chubb, & Sperling, 2016), we found performance on conjunctive target conditions was better than feature target conditions for one constituent feature dimension and worse for the other. In this study, we find performance on conjunctive target conditions is better than or equal to performance on both constituent feature target conditions. Methods: Targets were defined by luminance (the darkest items), shape (the most circular items), or their conjunction (the darkest and most circular items). Each stimulus display contained items that varied over two levels of each feature dimension. These two levels were chosen to be either more or less similar, resulting in four display types that were intermixed throughout the three blocked target conditions. Results: As expected, performance in all three target conditions was better when the stimuli differed more on the relevant dimension(s). When both the feature dimensions were sufficiently different, performance on the conjunction task was better than or equal to performance on both feature tasks. Conclusion: Given the visual search literature, it is perhaps surprising that participants can estimate the centroids of conjunctive targets at all, let alone better than they can constituent feature targets. The current findings suggest that conjunctive centroid judgments do not incur any cost to performance; rather, it seems they offer a performance advantage when the levels of both feature dimensions are sufficiently different.

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23.3014 **Ensembles Increase Search Efficiency When Predictive of Target Location** Phillip Witkowski[1](pwitkowski@ucdavis.edu), Joy Geng[1]; [1]University of California, Davis

Introduction: Research shows the visual system efficiently encodes peripheral objects as statistical representations, known as ensembles. However, few studies have explored the role of ensembles in visual search. Some models suggest that attention is drawn to ensembles with average qualities similar to the target (Im et al. 2015). Other models propose that learned ensemble-target associations facilitate visual search by cueing the location of the target. (Alvarez, 2011). Our project examines the function of ensembles to understand how they are used to facilitate target search and localization. Methods: Participants (N=20 per experiment) located a target line in one of two groups of lines, which formed ensembles in opposite locations on the screen. The average orientation of one ensemble matched the target orientation. The non-matching ensemble was 30 to 60 degrees different. Participants reported whether the target was in the left- or right-side ensemble, or was absent. In Experiment 1, the target was equally likely to be in all locations. In Experiment 2, the target was in the matching ensemble on 75% of trials and in either the non-matching ensemble or absent in 25% of trials. Results: Results from both experiments indicated that participants made significantly more initial saccades toward the matching ensemble, suggesting that the ensembles captured attention. Only in Experiment 2 did participants have faster response times, suggesting that participants used ensembles as cues to the target location after learning the ensemble-target association. This is further supported by evidence that participants were less likely to check the opposite ensemble after finding the target. This pattern suggests ensembles primarily influence visual search by acting as learned cues to the targets location. Conclusion: These results suggest that target-matching ensembles capture attention, but the effect on visual search is small unless there is a meaningful association between the ensemble and the target.

23.3015 **Limits to Attentional Selection of Features** Madison Elliott[1](maelliott1010@gmail.com), Ronald Rensink[1]; [1]The University of British Columbia

Longstanding questions exist about how features like color and orientation are selected by visual attention (Theeuwes, 2013; Brawn & Snowden, 1999; Treisman, 1988). Here, we present a new methodology to investigate this issue. This methodology is based on the perception of Pearson correlation r in scatterplots containing both a "target" population, and an irrelevant "distractor" population, which is to be disregarded. Observers viewed two such scatterplots side-by-side (each containing a target and a distractor population), and were asked to identify the one with the higher target correlation. Methods from Rensink & Baldridge (2010) were used to measure discrimination via just noticeable differences (JNDs) at 75% correct. Target items were always black, and the background always white. Distractor items differed in color or in orientation (Fig. 1). In our color manipulation, distractor dots were one of four shades of red. In our orientation manipulation, target dots were replaced with horizontal lines, and distractors were lines oriented at 30, 45, 60, and 90 degrees. In conditions where there were no distractor populations, JNDS were proportional to the distance from r = 1, consistent with the results of earlier studies. In two-population conditions, however, the slope of the JND lines increased, indicating interference from the irrelevant distractors. Two forms of interference were found. In our color manipulation, when the distractor dots were light pink (and most different from the target dots), interference was low, but when they were dark red (and most similar to the target dots), interference was high. Meanwhile, in our orientation manipulation, interference was high for distractors at 60 and 90 degree, but low for distractors at 30 and 45 degrees. This suggests that attentional selection may differ for different features. It also shows that this methodology may be a useful new way to examine attentional selection.

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23.3016 **Flexible prioritization of feature dimensions in perception of objects, ensembles, and social stimuli** Jose Rivera-Aparicio[1](jer4@williams.edu), Benjamin Lin[1], Jeremy Cone[1], Mariko Moher[1]; [1]Psychology Department, Williams College

As we look around the world, we identify items along many dimensions, such as color (looking for red as you search for an apple) and shape (looking for skinny rods as you search for a writing implement). Which dimension we prioritize may change, depending on our current goals. Using a task-switching paradigm, we examined whether certain feature dimensions are prioritized over others in visual processing of objects, ensembles, and social stimuli (e.g., animate creatures). On each trial, participants matched a target stimulus to one of two probe stimuli according to a particular dimension, such as color. After a few trials, the relevant dimension switched, forcing participants to focus on a previously ignored dimension (shape, in this case). We also investigated whether there was an asymmetry in switch costs; that is, whether it is easier to switch from one dimension to another (e.g., color to shape) than vice versa (e.g., shape to color). In Experiments 1a and 1b, participants sorted individual objects and homogeneous ensembles. As expected, switches in the sorting dimension led to increased reaction times. Furthermore, participants incurred a larger cost when switching from color to shape than vice versa, suggesting that color may be prioritized over shape for both individual objects and for homogeneous ensembles. In Experiment 2, participants sorted individual objects and heterogeneous ensembles. Switch costs were again observed; however, participants did not exhibit asymmetric switch costs for color or shape. In Experiment 3, participants sorted social stimuli. Switch costs were observed, and once again, participants exhibited a greater switch cost for switching from color to shape than vice versa. Together, these results suggest that while color is prioritized over shape in perception of objects and social stimuli, this may not be the case for heterogeneous ensembles. This underscores the importance of context in featural processing.

23.3017 **What modulate attentional parameters, familiarity or features?** Thomas Sørensen[1,2](thomasalrik@gmail.com), Yongming Wang[2,3], Xinlu Cai[2,3], Raymond Chan[2,3,4], Jonas Dall[1,2]; [1]Department of Communication and Psychology, Aalborg University , [2]Sino-Danish Center for Education and Research, [3]Institute of Psychology, Chinese Academy of Sciences, [4]CAS Key Laboratory of Mental Health

Several studies have investigated object-based capacity limitations of visual short-term memory (VSTM) (e.g. Luck & Vogel, 1997; Alvarez & Cavanagh, 2001). Recently research interest has turned from object-based processing towards the resolution of objects retained in short-term memory (e.g. Wilken & Ma, 2004). Although this research is highly relevant, there may be an inherent difference whether a stimulus can be easily classified in a discrete category, or if it belongs on a spectrum of a continuous category. Previous studies have shown that object based capacity of VSTM is not only limited by object complexity as argued by Alvarez & Cavanagh (2001), but also relates to familiarity and expertise (Sørensen & Kyllingsbæk, 2012; Dall, Watanabe, & Sørensen, 2016). Here we investigated the influence of two vectors of complexity, namely the number of features that the constitute an object versus the degree of familiarity with said object. We presented Chinese observers with a whole report design (see Sperling, 1960), consisting of four stimulus conditions. Chinese characters varied along two aspects: the word frequency and the number of strokes used in the character. Data were analysed using the Theory of Visual Attention (Bundesen, 1990) enabling us to isolate specific components of attention; VSTM capacity (K), as well as parameters like processing speed (C), and the threshold for visual perception (t0) (e.g. Ásgeirsson, Nordfang & Sørensen, 2015). The threshold of visual perception was not affected by the manipulation of stroke count, nor by character frequency. In turn we found a consistent pattern in both processing speed and capacity of VSTM revealing that observer performance was driven mainly by familiarity, and not stroke count, demonstrating that object complexity is dependent on the robustness of an observer's mental categories, rather than on the number of features in the object per se.

Acknowledgement: Sino-Danish Center for Education and Research

23.3018 **Blur as a Guide for Attention when Viewing Representational Visual Art** Christina Chao[1](clchao@uci.edu), Chai-Youn Kim[2], Emily Grossman[1]; [1]Department of Cognitive Sciences, University of California, Irvine, [2]Department of Psychology, Korea University

Background. Visual artists implement particular techniques (e.g. line arrangements, spatial layout, shadows) when creating representative 2-dimensional art piece. If and how an artist implements a particular technique can influence how viewers' attention is guided through the art piece. Here, we analyze the use of surrounding blur, which artists use to highlight or emphasize a component of the art piece (often an important figure or object). Given that blurred regions of visual scenes are less fixated than clear regions (Enns & MacDonald, 2012; DiPaola, et. at, 2013), how is the salience of highlighted objects impacted when blur is included in a visual art piece? Method. Regions of high salience were identified on each art piece through mouse clicks made by a naïve group of human subjects (N = 24). From these data we identified three commonly selected regions of interest (the primary face, a secondary face, and a salient object). A new group of subjects (N = 81) then participated in a change detection paradigm to measure the impact of blur on these three targeted salient regions, and a nonsalient control region. Blur was implemented as surrounding the object, on the object, with random placement in the image, or no blur. Results. We found a main effect of region on the ability to detect changes, but no significant effect of blur positioning. Blur did not modulate salience as measured through change blindness. An analysis of artistic ability revealed a trend towards higher salience when blur surrounded the targeted regions of interest. Conclusion. Our results suggest that implementing blur in an artistic sense alters the aesthetics of the image, but may be less effective for guiding attention. For the non-expert, blur may only be effective when everything but the region of interest is blurred.

23.3019 **'Mind contact': Might eye-gaze effects actually reflect more general phenomena of perceived attention and intention?**

Clara Colombatto[1](clara.colombatto@yale.edu), Benjamin van Buren[1], Brian Scholl[1]; [1]Department of Psychology, Yale University

Eye gaze is an especially powerful social signal, and direct eye contact has profound effects on us, influencing multiple aspects of attention and memory. Existing work has typically assumed that such phenomena are specific to eye gaze — but might such effects instead reflect more general phenomena of perceived attention and intention (which are, after all, what we so often signify with our eyes)? If so, then such effects might replicate with distinctly non-eyelike stimuli — such as simple geometric shapes that are seen to be pointing in various directions. Here we report a series of experiments of this sort, each testing whether a previously discovered 'eye gaze' effect generalizes to other stimuli. For example, inspired by work showing that faces with direct gaze break into awareness faster, we used continuous flash suppression (CFS) to render invisible a group of geometric 'cone ' shapes that pointed toward or away from the observers, and we measured the time that such stimuli took to break through interocular suppression. Just as with gaze, cones directed at the observer broke into awareness faster than did 'averted' cones that were otherwise equated — and a monocular control experiment ruled out response-based explanations that did not involve visual awareness, per se. In another example, we were inspired by the "stare in the crowd effect", wherein faces with direct eye gaze are detected faster than are faces with averted gaze. We asked whether this same effect occurs when it is cones rather than eyes that are 'staring', and indeed it does: cones directed at the observer were detected more readily (in fields of averted cones) than were cones averted away from the observer (in fields of direct cones). These results collectively suggest that previously observed "eye contact" effects may be better characterized as "mind contact" effects.

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23.3020 **The role of visual attention and high-level object information on short-term visual working memory in a change detection task.**

Moreno Coco[1](moreno.cocoi@gmail.com), Antje Nuthmann[1], Sergio Della Sala[1]; [1]Human Cognitive Neuroscience, Psychology, University of Edinburgh, UK

Some studies have suggested that visual attention and visual working memory (VWM) rely on shared processes and on the same limited resources (e.g., Chun 2011; Kiyonaga & Enger, 2013). Other studies, instead, have shown that visual attention and VWM might be dissociable and complementary (e.g., Johnson et al., 2008; Tas et al., 2016). In the present study, we investigated whether and to what degree visual attention is a necessary condition for effective encoding in VWM. Moreover, we explored how the memorability of objects depends on their high-level contextual information (e.g., their congruency or location). Twenty-six young participants performed a change detection task on 192 photographs of naturalistic scenes (96 experimental/change trials, 96 fillers/no change trials), while being eye-tracked. Three conditions of target object were considered: Congruency (it became another object), Location (it moved to another location) or Both (it changed and moved). We implemented the change using a gaze contingency paradigm. This was done to ensure that the object was always looked at during the study (or encoding) phase, prior to the retention interval (900 ms). We analyzed accuracy and response time for correct trials. We found that participants were better able to remember a change when Both features changed than when the target object changed Location (second best) or Congruency (worst and slowest). Crucially, the closer participants' eye fixations were to the target object, and the higher the similarity in scan-patterns during encoding and recall, the more likely it was that they correctly detected the change. These results suggest that visual attention is predictive of effective VWM, especially when the object does not change in location. This condition is difficult to discriminate by resorting on extra-foveal strategies only.

MOTION: BIOLOGICAL MOTION

Saturday, May 20, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

23.3021 **Identity Matching of Unfamiliar People from Point-Light Biological Motion**

Asal Baragchizadeh[1](asal.baragchizadeh@utdallas.edu), Alice O'Toole[1]; [1]School of Behavioral and Brain Sciences, University of Texas at Dallas

Point-light displays (PLDs) (Johansson, 1973) present compelling depictions of humans in motion and contain useful information for action (Dittrich, 1993; Kozlowski & Cutting, 1977) and gender perception (Kozlowski & Cutting, 1978). The few studies that have tested person recognition from PLDs provided weak support for biological motion as an identity cue, but only when participants were asked to name the familiar people depicted. Here, we examined the role of biological motion for identification using an identity-matching task (same or different person) for a large number of unfamiliar identities. We tested a broad range of actions, including walking, running, jumping forward, and boxing. Participants ($n = 39$) matched identities in 120 pairs of PLDs and responded using a 5-point scale (1: sure the same person to 5: sure different people). Subjects viewed PLD pairs of same action (e.g., both walking) and different actions (e.g., walking and boxing). Results showed performance accuracy well above chance in the same-action condition (mean a-ROC = .70, 95% CI [0.68, 0.73], $p < 0.0001$). In the different-action condition, accuracy was moderate and also greater than chance (mean a-ROC = .59, 95% CI [0.57, 0.62], $p < 0.0001$). As expected, identity discrimination was more accurate when the pairs performed the same action rather than different actions ($p < 0.0001$). For same-action trials, the quality of identity information varied with action type (cf., also Loula et al., 2005). Jumping forward yielded the highest a-ROC score (M=.77, SD=.22), followed by walking (M=.70, SD=.09), and running (M=.63, SD=.21). Boxing yielded the lowest a-ROC score (M=.62, SD=.33). In combination with previous work (Cutting & Kozlowski, 1977; Beardsworth & Buckner, 1981; Loula et al., 2005), the current results suggest that biological motion cues not only provide information reliable for discriminating the identity of familiar people, but also for discriminating unfamiliar identities.

23.3022 **Categorizing features of coordination from joint actions**

Joseph Burling[1](jmburling@ucla.edu), Hongjing Lu[1]; [1]University of California, Los Angeles

Our ability to perceive others' actions and coordinate our own body movements accordingly is essential for interacting with the social world. Interacting with others often requires precise control of our own limbs and body to adapt to sudden changes in movement. However, during passive observation of joint action between two persons, are observers sensitive to specific features of coordinated movement, and do groups of features emerge for different types social actions? Participants viewed short video sequences showing two actors performing ten different interpersonal interactions, such as shake hands, high-five, etc. In some trials, temporal misalignments were introduced that temporally shift one actor's movements forward or backward in time relative to the partner actor. The temporal offsets varied in magnitude for each lead/lag condition (exact timing depended on the total action duration). Participants rated degree of interactiveness on a scale of 1–7. First, we compared human interactiveness ratings across joint actions and found a significant interaction between offset magnitude and joint action type, $p(F_{9,454} = 10.7) < .001$. We found that temporal misalignment did not alter participant ratings for some joint actions, e.g, shake hands, tug-of-war, arguing and threaten. However, ratings varied depending on the temporal direction of misalignments for other joint actions, such as catch, high-five, chicken dance, skipping and threaten. Second, based on rating distributions across joint actions, we fit a generative probabilistic cluster model to group the distributions into latent classes, revealing shared characteristics among sets of joint actions. The resulting clusters organized joint actions by the dimensions of average rating score and sensitivity to offset directionality. Further analysis on the clustered structure of joint actions revealed that global motion synchrony, spatial proximity between actors, and local, brief, but highly salient moments of interpersonal coordination are critical features that impact judgments of interactiveness.

Acknowledgement: NSF BCS-1353391

23.3023 **Subcortical and cortical responses to local biological motion as revealed by fMRI and MEG** Dorita Chang[1](changd@hku.hk), Hiroshi Ban[2,3], Yuji Ikegaya[2,4], Ichiro Fujita[3], Nikolaus Troje[5]; [1]Department of Psychology, The University of Hong Kong, Hong Kong, [2]Center for Information and Neural Networks (CiNet), NICT, Japan, [3]Graduate School of Frontier Biosciences, Osaka University, Japan, [4]Graduate School of Pharmaceutical Sciences, The University of Tokyo, Japan, [5]Department of Psychology, Queen's University, Canada

We report findings from both human fMRI (n = 35), and MEG (n = 10) experiments that tested neural responses to dynamic ("local", acceleration) cues in biological motion. We measured fMRI responses (3T Siemens Trio, 1.5 mm3) to point-light stimuli that were degraded according to: 1. spatial coherency (intact, horizontally scrambled with vertical order retained, horizontally scrambled with vertical order inverted); 2. local motion (intact, constant velocity); and 3. temporal structure (intact, scrambled). Results from MVPA decoding analyses revealed surprising sensitivity of subcortical (non-visual) thalamic area ventral lateral nucleus (VLN) for discriminating local naturally-accelerating biological motion from constant velocity motion, in addition to a wide cortical network that extends dorsally through the IPS and ventrally, including the STS. Retaining the vertical order of the local trajectories resulted in higher accuracies than inverting it, but phase-randomization did not affect (discrimination) responses. In a separate experiment, different subjects were presented with the same stimuli while magnetic responses were measured using a 360 channel whole head MEG system (Neuromag 360, Elekta; 1000 Hz sampling frequency). Results revealed responses in much of the same cortical network identified using fMRI, peaking at 100-150 ms, and again at 350-500 ms after stimulus onset during which we also observed important functional differences with greater activity in hMT+, LO, and STS for structure-from-motion versus the local natural acceleration stimulus, and greater early (V1-V3) and IPS activity for the local natural acceleration versus constant velocity motion. We also observed activity along the medial surface by 200 ms. The fact that medial activity arrives distinctly following early cortical activity (100-150 ms), but before the 350-500 ms window suggests that the implication of thalamic VLN for biological motion perception observed with fMRI may have arisen from early cortical responses, but not higher order extrastriate cortex.

23.3024 **Examining the role of motion in expert object recognition.** Simen Hagen[1](shagen@uvic.ca), Quoc Vuong[2], Lisa Scott[3], Tim Curran[4], James Tanaka[1]; [1]Department of Psychology, University of Victoria, [2]Institute of Neuroscience, Newcastle University, [3]Department of Psychology, University of Florida, [4]Department of Psychology and Neuroscience, University of Colorado Boulder

Motion information contributes to multiple functions during the early stages of vision (e.g., attract attention, segment objects from the background); however, it also contributes to later stages of object recognition. For example, human observers can detect the presence of a human, judge its actions, judge its gender and identity simply based on motion cues conveyed in a point-light display. In the current study we examined whether real-world experience in an object domain can influence the sensitivity to the motion of objects within that domain. People with- and without-extensive experience in the bird domain were shown point-light displays of upright and inverted birds in flight, or upright and inverted human walkers, and asked to discriminate them from spatially scrambled point-light displays of the same stimuli. While the spatially scrambled stimuli retained the local motion of each dot of the moving objects, it disrupted the global percept of the object in motion. To estimate a detection threshold in each object domain, we systematically varied the number of noise dots in which the stimuli was embedded using an adaptive stair-case approach. Contrary to our prediction, both groups showed equal sensitivity to global bird motion with no inversion cost. However, consistent with previous work showing a robust inversion effect for human motion, both groups were more sensitive to upright human walkers than their inverted counterparts. Thus, at least under the conditions of our experiment, our result suggests that experience in the bird domain does not influence the sensitivity to global bird motion. However, the inversion effect with humans, but not with birds, suggest that motion recognition within the two domains rely on different mechanisms.

Acknowledgement: ARI grant W5J9CQ-11-C-0047 and NSF

23.3025 **Motion information reducing manipulations can bias the discrimination of sex in biological motion perception** Eric Hiris[1](e-hiris@uwlax.edu), Danielle Brzezinski[1], Alayna Stein[1]; [1]Department of Psychology, University of Wisconsin - La Crosse

The relative importance of motion and form information in biological motion perception has been debated in the biological motion literature. Several techniques have been used to study the role of form information in biological motion perception, including presenting stationary single frames of biological motion to remove motion entirely, or reducing the motion information available in the display by (1) presenting sequential position walkers where the point-lights move on the limbs across frames (Beintema & Lappe, 2002; Beintema, Georg, & Lappe, 2006) or (2) presenting size-changing biological motion where the size of the entire biological motion display varies across frames (Lappe, Wittinghofer, & de Lussanet, 2015). We compared these various methods of investigating the role of form in biological motion perception. Specifically, we compared performance on a sex discrimination task in biological motion in four conditions: (1) normal biological motion, (2) static frame of normal biological motion, (3) sequential position biological motion, and (4) size-changing biological motion. The results showed that discriminability of the sex of the actor, as measured by the slope of the best fitting logistic regression functions, was highest in normal biological motion and significantly lower in the other conditions that remove or reduce motion information. In addition to these expected results, sequential position biological motion and size-changing biological motion also created a significant bias in sex discrimination where the displays were biased to be perceived as more male (as measured by the 50% point of the function). These results suggest that some manipulations of biological motion stimuli may create significant biases in biological motion perception that are not likely due to the removal of motion information per se. Future research is needed to explain the basis of the bias and may lead to greater understanding of the mechanisms of biological motion perception.

23.3026 **Priming and Adaptation in Biological Motion Perception** Hongjing Lu[1,2](hongjing@psych.ucla.edu), Yujia Peng[1]; [1]Department of Psycholology, UCLA, [2]Department of Statistics, UCLA

Recent perceptual experiences can alter visual perception in two distinct ways: priming and adaptation-induced aftereffects. While priming typically leads to facilitation effects, associated with faster and/or more accurate responses to the same stimulus, adaptation results in repulsive aftereffects, revealed by slower and/or less accurate responses to the same stimulus. In the present study, we examined priming and adaptation effects in biological motion perception, and their interactions with part/whole body structure. On each trial, participants first viewed a walking action (S1) presented as either the whole-body motion, or as subparts of body movements (bipedal leg movements, bilateral arm-leg movements with the same motion direction, and unilateral arm-leg movements with the opponent motions). The S1 stimuli were presented in the forms of point-light or skeleton walkers for either a short duration (100 ms) or a long duration (500 ms). After the presentation of S1, a point-light whole-body walker was shown briefly as the second stimulus (S2) for 200 ms. Participants were asked to judge the facing direction of the walker in S2. Results showed that with a short duration of S1 (100 ms), both whole-body and subpart movements in S1 elicited robust priming effects but with different facilitation magnitudes. For subpart movements, bipedal feet movements and bilateral arm-leg movements showed stronger priming effects than did unilateral arm-leg movements, suggesting that some subparts of body movements may be encoded in the hierarchical representation of actions. When the S1 stimulus was presented for a long duration (500 ms), the whole-body skeleton display yielded an adaptation effect, and no other conditions yielded aftereffect, suggesting that biological motion adaptation depends on the global whole-body representation of actions. These findings also indicate that a transition from priming to adaptation depends on the temporal duration of the first stimulus.

Acknowledgement: NSF BCS-1353391

23.3027 **Seeing illusory body movements in human causal interactions** Yujia Peng [1](yjpeng@g.ucla.edu), Hongjing Lu[1,2]; [1]Department of Psychology, University of California Los Angeles, [2]Department of Statistics, University of California Los Angeles

Goal-directed actions entail causality. One person moving his limbs in a certain way causes another person to react, creating a meaningful interaction. For example, seeing a friend throwing a ball towards you causes you to raise your arm to catch it. If humans are sensitive to the causal relation between two individual actions, then one action may provide information about the causal history of a static frame of the other action: the causal actions that generated the posture change over time. The present study examined whether human causal interactions can induce a percept of gradual motion between two distinct postures. The stimuli involved an interactive action, with one actor throwing an object and another actor catching it. The object itself was not presented. On each trial, the thrower was shown first, followed by a brief presentation of the catcher, while the thrower continued his movements in the entire trial. During the brief presentation, the catcher demonstrated either a sudden posture change (two static posture frames) or a gradual posture change with smooth movements (multiple frames). The two actors either showed a meaningful interaction (i.e. they faced each other), or a non-interactive situation (i.e. they faced away), or were presented upside-down. Participants judged whether the catcher showed a sudden or gradual posture change. We found that in the interaction condition, the proportion of trials in which a sudden change was misidentified as a gradual change was significantly higher than in the non-interactive or the inverted conditions. This finding suggests that observers were more likely to perceive illusory gradual motions when body movements were consistent with a causal interpretation of two actors interacting to achieve a common goal. To account for the human results, a Bayesian model was developed that incorporated inferred expectations based on causal actions.

Acknowledgement: NSF BCS-1353391

23.3028 **How Do We Recognize People in Motion?** Noa Simhi[1](noa.louisa@gmail.com), Galit Yovel[1,2]; [1]The School of Psychological Sciences, Tel-Aviv University, [2]The Sagol School of Neuroscience, Tel-Aviv University

Person recognition has been primarily studied with static images of faces. However, in real life we typically see the whole person in motion. This dynamic exposure provides rich information about a person's face and body shape as well as their body motion. What is the relative contribution of the face, body and motion to person recognition? In a series of studies, we examined the conditions under which the body and motion contribute to person recognition beyond the face. In these studies, participants were presented with short videos of people walking towards the camera and were asked to recognize them from a still image or a video that was taken on a different day (so recognition was not based on clothing or external facial features). Our findings show that person recognition relies primarily on the face, when facial information is clear and available. However, when facial information is unclear or at a distance the body contributes to person recognition beyond the face. Furthermore, although person recognition based on the body alone is very poor, the body can be used for person recognition when presented in whole person context and in motion. In particular, person recognition from uninformative faceless heads attached to headless bodies was better than recognition from the body alone. Additionally, person recognition from dynamic headless bodies was better than recognition from multiple static images taken from the video. Overall our results show that when facial information is clearly available, person recognition is primarily based on the face. When facial information is degraded, body, motion and the context of the whole person are used for person recognition. Thus, even though the face is the primary source of information for person identity, information from the body contributes to person recognition in particular in the context of the whole person in motion.

23.3029 **Dynamics of multistable biological motion perception** Louisa Sting[1](louisa.sting@student.uni-tuebingen.de), Leonid Fedorov[2], Tjeerd Dijkstra[2], Howard Hock[3], Martin Giese[2]; [1]Department of Computer Science, Cognitive Science Center, University of Tuebingen , [2]Center for Integrative Neuroscience, HIH, UKT, University of Tuebingen, [3]Center for Complex Systems and the Brain Sciences, Department of Psychology, Florida Atlantic University

The dynamic stability of percepts has been extensively studied in low-level motion (Hock et al. 2003, 1996). A manifestation of dynamic stability is the perceptual hysteresis shown for a pair of mutually exclusive motion stimuli. So far hysteresis effects have not been investigated in biological motion perception. Its measurement requires a parameter that controls the relative bias of perception for the two alternatives. We developed such a stimulus for biological motion perception and investigated dynamic stability. METHODS: Our stimulus is based on the fact that body motion perception from two-dimensional movies can be bistable (Vanrie et al. 2004), alternating between two different percepts. We developed a new stimulus by random sampling two shaded volumetric walkers covered with 1050 circular discs. The fraction of discs drawn from either walker is a hysteresis parameter that allows to vary gradually the preference for two perceived walking directions. We realized two experiments: I. Measurement of the times before the first perceptual switch as function of the hysteresis parameter. II. Measurement of a hysteresis loop, varying the hysteresis parameter gradually up and down. This experiment adapted the Modified Method of Limits by (Hock et al. 1993). RESULTS: Experiment I shows that, dependent on the hysteresis parameter, the new stimulus can induce both an unambiguous perception of walking direction and perceptual bistability. The average switching time is smallest if both percepts are equally likely and it depends systematically on the hysteresis parameter ($p < 10\text{-}15$). Experiment II measured the percept probabilities as function of the hysteresis parameter. These probabilities are significantly dependent on previous values of the parameter (i.e. whether it was increasing or decreasing), implying perceptual hysteresis ($p < 0.01$). CONCLUSION: We demonstrated that body motion perception, like low-level motion perception, shows indicators of dynamic multi-stability.

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Visual Search: Features and Objects

Saturday, May 20, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

23.3030 **Target prevalence in a search task transfers to another search task if their search items look visually similar** Han-Gyeol Son[1](wanz1091@gmail.com), Hyung-Bum Park[1], Joo-Seok Hyun[1]; [1]Department of Psychology, Chung-Ang University

The probability of target presence can affect accuracy and speed of a visual search task, and this is known as target prevalence effect. The present study reports that target prevalence of a visual search that was once performed can influence another subsequent search with neutral target prevalence (i.e., 50%) if the search arrays are visually similar. In the experiments, participants performed two independent search tasks across trials where one had the target prevalence of 10, 50, or 90% (prevalence-search), while the other had 50% (neutral-search). In the target-mismatch condition, the target for each task differed in the target-relevant feature (e.g., different Landolt gap-openness), but the search items across the two tasks shared a target-irrelevant feature (e.g., rounded black Landolt Cs), making the search arrays look visually similar. Conversely, in the array-mismatch condition, the target for each task shared the target-relevant feature (e.g., the same Landolt gap-openness), but the search items across the two tasks differed in their target-irrelevant feature (e.g., rounded black Landolt Cs vs. angulated white Landolt Cs), making the search arrays look dissimilar. The results showed that target prevalence manipulation of the prevalence-search influenced accuracy and RTs of neutral search trials exclusively in the target-mismatch condition, indicating that target prevalence of a search task can transfer to another search task if their search items look similar. They further suggest that contextual information such as target prevalence in a daily search task can influence another search task if the tasks share objects that are visually similar rather than dissimilar.

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23.3031 Motor Biases Do Not Account for the Low Prevalence Effect Chad Peltier[1](peltie11@gmail.com), Mark Becker[1]; [1]Michigan State University

The low prevalence effect (LPE) is an increase in miss errors as target prevalence decreases in a visual search task. There are three proposed causes of this effect: a decrease in quitting threshold, a conservative shift in criterion, and a target absent motor bias. Per the motor bias hypothesis, the frequent target absent responses that occur in low target prevalence searches bias the target absent motor response. Occasionally this prepotent motor bias results in an erroneous target absent button press despite a target detection. Fleck and Mitroff (2007) found that the LPE was eliminated when observers could make a corrective response to overcome the prepotent target absent response. Several researchers have since found that allowing a corrective response or controlling for motor biases does not eliminate the LPE. Here we predict that motor biases will influence search performance only when the response to response time between trials is minimal. We investigate our hypothesis by allowing corrective responses under different conditions. In Experiment 1 we manipulate target prevalence and set size. Results show that motor biases contribute to the LPE only when the set size is small, thereby producing short response to response intervals between trials. In Experiment 2, we manipulate the Inter-Response-Interval (IRI) to find the time it takes to eliminate effects of motor biases on the LPE. The results show that as the IRI increases, the effects of motor biases decrease. Overall, we show that motor biases not only fail to account for the LPE, but also fail to influence search performance when target presence judgements are separated by enough time. These results indicate that researchers do not need to control for motor biases in time consuming serial search tasks and that real-world searches where trials last several seconds are unlikely to be influenced by motor biases.

23.3032 Target prevalence in a visual search task differentially modulates lure effects from visual working memory Beatriz Gil Gómez de Liaño[1](bgil.gomezdelianno@uam.es), Trafton Drew[2], Daniel Rin[1], Jeremy Wolfe[3]; [1]Universidad Autónoma de Madrid, [2]University of Utah, [3]Brigham & Women's Hospital-Harvard Medical School

Performance on Visual Search (VS) is driven by bottom-up, stimulus-based information and the top-down state of the observer: What is she looking for? What else is on her mind? Here, we investigate the top-down effects of holding task-irrelevant objects in working memory during VS. Observers searched through16 real-world objects looking for a target, while maintaining other specific objects in working memory (1 or 4). The memorized objects could appear as "lures": distractors in the VS task. We varied target prevalence in VS (4%, 50%, 96%, and a 100% target present condition). Our results demonstrate that lure effects clearly depend on target prevalence. For target absent trials, RTs are longer when lure is present for almost all conditions, particularly in the 96% condition, and this effect did not interact with target prevalence. This slowing may reflect the cost of recognizing and disengaging from the lure. For target present trials, at low (4%) prevalence, lures significantly decreased RTs ($p< .001$), while there was no effect of lures for 50% and 96%. This speeding may be related to the elevation of miss error rates. Perhaps finding a lure encouraged quicker search termination, which could be related to the "satisfaction of search" effect in radiology. In fact, real world search tasks vary widely from low prevalence tasks like radiologists screening for cancer, or high prevalence tasks like looking for posts of a trending topic in Twitter. The present results suggest that the effects of distracting information held in working memory depend on the nature of the VS, and remind us that prevalence has complex effects on search performance.

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23.3033 Temporal dynamics of attentional templates Anna Grubert[1](anna.k.grubert@durham.ac.uk), Martin Eimer[2]; [1]Department of Psychology, Durham University, [2]Department of Psychological Sciences, Birkbeck, University of London

Attentional templates (representations of target features) are activated prior to search to guide spatial attention to target-matching events in the visual field. To investigate the temporal dynamics of preparatory template activation, we developed a new rapid serial probe presentation technique and measured N2pc components to these probes during single-colour and multiple-colour search. Participants searched for colour-defined targets that appeared together with different-colour distractors in circular search displays. During this task, a continuous stream of circular probe displays appeared at a different location closer to fixation. These task-irrelevant displays contained one coloured and five grey items. All probe and search displays were presented for 50ms and were separated by a 200ms stimulus onset asynchrony. In Experiment 1, target colour was constant (e.g., red), and probe arrays contained either a target-colour or a distractor-colour singleton. Only target-matching probes triggered an N2pc, indicative of template-guided attentional capture. No N2pc was elicited for probes that appeared directly after a preceding search display and the N2pc was largest for probes that immediately preceded the next search display. This demonstrates that template activation is not constant, but is modulated in line with temporal task parameters. A control experiment showed that the apparent transient template de-activation following search displays is not an automatic consequence of target identity or response-related processing. Analogous N2pc results were found in Experiment 2, where target colour alternated predictably across successive search displays (e.g., red, green, red), and singleton probes either matched the previous or the upcoming target colour. Both types of probes triggered a similar N2pc pattern, suggesting simultaneous activation of colour target templates during multiple-colour search even when the upcoming target colour is known. These results show that our new rapid serial probe presentation method can provide novel electrophysiological insight into the time course of attentional templates.

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23.3034 Visual search through displays of data Christine Nothelfer[1](cnothelfer@gmail.com), Steven Franconeri[2]; [1]Northwestern University

With the increasing availability and importance of data, the human visual system serves as a critical tool for analysis of patterns, trends, and relations among those data. Building on recent translational visual search work in domains like baggage screening (e.g., Mitroff et al., 2015) and radiology (e.g., Wolfe, 2016), we explored how different ways of representing data values can lead to efficient or inefficient visual processing of the relations between the values in a data pair. We asked participants to find a particular relation among the opposite relation (e.g., small/large value pairs among large/small), under a variety of common, and manipulated, data encoding methods: bullet graphs (one value as a bar, the other as a threshold dash through the bar), line graphs, connected dash graphs, area graphs, dash graphs (lines placed where the tops of bars in a bar graphs 'would be'), adjacent bars, and separated bars. Displays were divided into quadrants containing 1-5 data pairs each, for a total set size of 4-20 items. Participants were asked to quickly indicate which quadrant contained the target data pair. The choice of data depiction led to enormous differences in processing efficiency for relations between values (ranked fast to slow in the order listed above), from flat search slopes (line graphs), medium search slopes of 69 ms/pair (dash graphs), and severely steep search slopes of 115 ms/pair (separated bar graphs), one of the most ubiquitous encoding types. Visual search for relations can be strikingly serial, but performance can improve substantially with small changes to displays. Exploring visual search and relation processing in the context of data visualization displays may provide a rich case study for both basic research on the mechanisms of search, but also concrete guidelines for the students and scientists who use vision to process and convey patterns in data.

23.3035 Visual search in large letter arrays containing words: are words implicitly processed during letter search? Maria Falikman[1,2,3](maria.falikman@gmail.com); [1]Department of Theoretical and Applied Linguistics, Lomonosov Moscow State University, [2]Cognitive Research Lab, National Research University Higher School of Economics, [3]Department of Psychology, Russian Academy for National Economy and Public Affairs

The word superiority effect (Cattell, 1886) is discussed in psychology for more than a century. However, a question remains whether automatic word processing is possible without its spatial segregation. Our previous studies of letter search in large letter arrays containing words without spatial segregation revealed no difference in performance and eye movements when observers searched for letters always embedded in words, never embedded in words, or when there were no words in the array (Falikman, 2014; Falikman, Yazykov, 2015). Yet both the percentage of participants who noticed words during letter search and their subjective reports whether words made search easier or harder significantly differed for target letters within words and target letters out of words. In the current study, we used the Processes Dissociation Procedure (Jacoby, 1991) to investigate whether words are processed implicitly when observers search for letters. Two groups of participants, 40 subjects each, performed 1-minute search for 24 target letters (either Ts, always within words, or Hs, always out of words) in the same letter array of 10 pseudorandom letter strings, 60 letters each, containing 24 Russian mid-frequency nouns. After that, they filled in two identical word-stem completion forms, each containing the same 48 word beginnings (24 for words included in the array). First, the participants were instructed to use words that could appear in the search array ("inclusion test"), then – to avoid using such words ("exclusion test"). Comparison of conscious and unconscious processing probabilities revealed no difference between them (with the former not exceeding 0.09 and the latter not exceeding 0.11), no difference between the two conditions, and no interaction between the factors. This allows concluding that, despite of subjective reports, words embedded in random letter strings are mostly not processed either explicitly or implicitly during letter search, and that automatic unitization requires spatial segregation.

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23.3036 **The guidance of attention by features and feature configurations during shape/shape conjunction search** Cody McCants[1](c-mccan03@mail.bbk.ac.uk), Nick Berggren[1], Martin Eimer[1]; [1]Department of Psychological Sciences, Birkbeck, University of London, UK

During visual search, attentional templates guide the allocation of attention to objects with template-matching features. When targets are defined by a conjunction of two colours, these guidance processes appear to operate independently for each of these features. As a result, there is no effective attentional guidance when targets defined by a particular configuration (e.g., blue above red) are accompanied by a distractor with the reverse configuration (e.g., red above blue) in the same display. This has been demonstrated recently with ERP markers of attentional selectivity (N2pc components; Berggren & Eimer, 2016). The present study investigated attentional guidance in tasks where targets were defined by the configuration of two different shapes (e.g., hourglass above circle). Participants reported the presence or absence of such combined-shape targets while ignoring non-target items that could be non-matching (e.g. hexagon above cross), partially-matching (e.g., cross above circle) or fully-matching in the reverse configuration (e.g., circle above hourglass). The pattern of N2pc components measured for target-present and target-absent displays again revealed evidence for independent attentional guidance by each of the two target-defining shapes. However, and in contrast colour configuration search, attention was also guided by shape configuration. When a target and a reverse-configuration nontarget appeared in the same display, an N2pc was triggered by the target, although it was delayed and attenuated relative to the target N2pc triggered in the absence of a template-matching distractor. Similar N2pc results were observed when the two shapes were adjacent (thus forming a single object) and when they appeared in different quadrants, demonstrating that guidance by shape configuration was not simply based on search templates for fused target objects. Results show that in contrast to colour, conjunction search in the shape domain can be guided by target templates for spatial configurations.

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23.3037 **Binding feature distributions to locations and to other features** Andrey Chetverikov[1,2](andrey@hi.is), Gianluca Campana[3,4], Árni Kristjánsson[1]; [1]Faculty of Psychology, School of Health Sciences, University of Iceland, Iceland, [2]Department of Psychology, Saint Petersburg State University, Russia, [3]Department of General Psychology, University of Padova, Italy, [4]Human Inspired Technology Research Centre, University of Padova, Italy

Real world objects have a variety of features with different probability distributions. A tree leaf can have a unimodal hue distribution in summer that changes to a bimodal one in autumn. We have previously shown that perceptual systems can learn not only summary statistics (mean or variance), but also distribution shapes (probability density functions). To use such information observers need to relate it to spatial locations and other features. We investigated whether observers can do this during visual search. Ten observers looked for an odd-one-out line among 64 lines differing in orientation. Each observer participated in five conditions consisting of interleaved prime (5-7 trials) and test (2 trials) streaks. Distractors on prime streaks were randomly drawn from a mixture of two Gaussian distributions (10° SD) or a mixture of Gaussian and uniform (20° range) with means located ±20° from a random value. The target was oriented 60° to 90° away from the mean of the resulting bimodal distribution. During test streaks, both target and distractor mean changed with distractors randomly drawn from a single Gaussian distribution. In the spatially-bound condition, the two prime distributions were spatially separated with distractors from one distribution on the left, the rest on the right. In the feature-bound condition, distractors from one distribution were blue, the others yellow (target color was randomly yellow or blue). We analyzed RTs on test trials by distance in feature space relative to distractor distributions on prime streaks and target location or color. Separation of distributions by location and, to a lesser extent, by color, allowed observers to encode them separately. However, the properties of one distribution affected encoding of another. The results demonstrate the power and limitations of distribution encoding: observers can encode more than one distribution simultaneously, but each resulting representation is affected by other distributions.

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23.3038 **Does Orientation Matter? The Effects of Target Orientation in Multiple Target Visual Search** Stephen Adamo[1], Joseph Nah[1], Andrew Collegio[1], Paul Scotti[1], Sarah Shomstein[1]; [1]Department of Psychology, The George Washington University

Multiple-target visual searches, where more than one target can be present in a search array, are subject to Subsequent Search Miss (SSM) errors: a decrease in second target detection after successful detection of the first target. While SSM errors have been known in radiology for over 50 years, their underlying cause remains elusive. The perceptual set account predicts that SSM errors are driven by target similarity, such that a second target is more likely to be missed if it is dissimilar to a previously found target. Biggs et al., (2015) demonstrated initial strong evidence for this account by exploring how different types of target similarity affect SSM errors. If a second target shared the identity, color, or category of a previously found target, observers made fewer SSM errors. However, target orientation was not investigated as a measure of similarity. Here, we investigated SSM errors in a multiple target search, with targets that appeared in the same or different orientation. Observers were asked to search for up to two targets: high- or low-salience target letter T's and L's, amongst low-salience pseudo T/L distractors. Four search items were independently rotated either 0°, 90°, 180°, or 270° and presented for 400ms equally centered around a fixation point. The results demonstrated an SSM effect with decreased low-salience target accuracy after a high-salience target was detected compared to single, low-salience, target accuracy. However, there was improved second target detection when both targets shared identity (i.e., both T's or both L's) and orientation, compared to when both targets were either different types (i.e., a T and an L) or different orientations (e.g., two T's of different orientations). These results provide novel evidence suggesting that SSM errors are impacted by the rotation of targets, providing further evidence for the perceptual set account.

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23.3039 **The Influence of Color and Form Information on Visual Search Guidance and Verification Times** Mark Becker[1](becker54@msu.edu), Ryan Wujcik[1], Chad Peltier[1]; [1]Department of Psychology, Michigan State University

In visual search, a working memory representation of the search target guides attention to similar items, and is used to verify whether an inspected item is the target. Research comparing picture to text-based search cues finds that picture cues produce better guidance (reduced time to first fixate the target) and shorter verification times (reduced time between fixating the target and response). These findings suggest that a high fidelity working memory representation benefits both search guidance and target verification. Here we investigated the source of this picture cue benefit to determine how the cue's visual form and/or color information differentially impact guidance and verification times. Given that visual acuity drops precipitously with eccentricity, visual form information may be unlikely to influence guidance to the periphery, but may benefit verification. By contrast, color information is likely to influence guidance but may have little influence on verification times. To test the impact of color and visual form information, subjects searched colored arrays of photo-realistic objects while we manipulated the cue type. Cues were gray-scaled pictures, color pictures, text labels, or text-labels with color information (e.g., "blue shoe"). Tracking eye movements allowed us to parse reaction times into guidance and target verification phases. Results show that color information improved guidance, and did so to a similar extent for both picture and text cues. To our surprise, form information also improved guidance and this improvement was additive with the color benefit, and of about the same magnitude. In terms of verification times, form information reduced verification times, but color information did not reduce verification times for text-based cues. Finally, during guidance, color's impact occurred within the first fixation while the benefit of form information was slightly delayed. These results suggest unique impacts of form and color information on search guidance and target verification processes.

23.3040 The Grass isn't Greener: No detriment for red-green color deficiency in search for camouflaged targets

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Visual search is an essential task we perform every day. Color is an important feature for guiding search, yet those with visual color impairments often live normal and unassisted lives (Wolfe, 1994). Those with red-green color vision deficiencies are at a specific disadvantage when discriminating natural terrains, which often lie within wavelengths between 557 – 589 mμ (Hendley & Hecht, 1949). Despite this, those with color-deficiencies are able to successfully analyze complex natural scenes in recognition tasks, suggesting some sort of visual accommodation for impoverished chromatic information (Gegenfurtner, Wichmann & Sharpe, 1996). Previously, we investigated how search changes in natural images when targets are not only camouflaged, but also presented without color information (in grayscale), finding that accuracy suffered for those searching without color information. However, it is not yet understood how those with deficiencies search natural images for obscured targets. In this experiment, we compared those with normal vision to those with red-green color deficiencies in a visual search task for a camouflaged target in natural, wooded images. We found no significant differences between those with color-deficiencies and those with normal vision in response time or accuracy, suggesting two possible conclusions. First, that color information is not necessary to guide attention in this unique type of search task. Alternatively, those with red-green deficiencies might reprioritize visual information in order to guide search in natural scenes.

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23.3041 Physical Properties Guide Visual Search for Real-world Objects

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Finding a missing earring in a jewelry box can be a frustrating challenge, but it becomes easier if the earring differs in color, shape, or size from other items in the box. These visual attributes and many others help to guide our attention toward the items of interest. Does our knowledge of objects' physical properties – e.g., that the earring is hard, smooth, and dense – also guide our search? Would we be faster to locate the earring if it appeared among soft objects rather than hard ones? Here, we tested observers' ability to use their physical knowledge about everyday objects to guide their attention in visual search. We presented participants with search arrays comprising sixteen objects. The objects were rated on perceived hardness by a separate group of online participants, and in each search array a target object was paired either with 15 distractors of similar hardness (e.g., soft target among soft distractors) or 15 distractors of different hardness (e.g., soft target among hard distractors). Participants (n=24) were asked to find the target object among the distractors after viewing a word label of that target for 1s. They pressed a key after locating the target and then indicated the target location with a mouse click. We found that participants were faster to locate a target object when it appeared among distractors of different hardness (1.28s±0.05) vs. distractors of similar hardness (1.64s±0.08; $t(23)=5.04$; $p< 0.001$). Critically, this effect was intact after controlling for any influences of image luminance, contrast, color, shape, and semantic content. Our results indicate that observers can use their knowledge of objects' physical properties to guide their visual search toward likely targets. These findings point toward an important role of physical knowledge in guiding how we engage with visual scenes in daily life.

23.3042 Task-irrelevant optic flow guides overt attention during visual search

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It is known that basic visual features such as color or contrast capture attention. Recent research suggests that optic flow also attracts attention even when it is irrelevant to participants' task. However, the impact of an individual's attentional set on attentional capture to optic flow is poorly understood. In two experiments, we examined whether task-irrelevant optic flow induces attentional capture under different conditions of a participant's attentional set. The first experiment aimed to confirm the course of attentional guidance via optic flow in a visual search task. Participants had to find a target, Gabor patch, with an orientation different from distractors. Prior to onset of the search display, a task-irrelevant optic flow display was presented for 1, 3, or 5 sec. Results indicated that all three optic-flow exposure conditions yielded faster search times when the target was presented at the expanding point of optic flow (EPOF) than when the target happened at another location. Moreover, eye movement analysis revealed that the first saccade headed for EPOF. In the second experiment, a task irrelevant color circle, was presented in the search display. This procedure ensured that participants' attention was directed to the color circle which was concurrently presented with a target if participants are sensitive to feature singletons. However, results revealed that the optic flow continued to strongly guide attention. In other words, a color singleton does not override attentional capture created by optic flow. These results suggest that optic flow quickly guides an attention-forward expanding point regardless of participants' attentional set.

23.3043 Effects of prior knowledge on visual search in depth

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In visual search, if observers know the target has a certain feature in advance, they can restrict search to potential elements that share this feature. A limited set of features (e.g. color and motion) can support this phenomenon. What about knowledge of target depth, signaled by binocular disparity? Can observers restrict search to disparity-defined depth planes? Previous studies have come out with somewhat different results in reaction time and search efficiency. We hypothesized more stable guidance by disparity might be seen if more time was provided for observers to resolve depth in the stereoscopic displays. In experiment 1, observers searched for 2 among 5s. In order to provide the time prior to search, figure-eight placeholders were used. Placeholders were presented in depth from the beginning of each trial and then changed into 2s or 5s after a 1500msec delay. Three conditions were compared: one depth plane or two depth planes with targets cued to be in the front or back plane. Searches in both two-depth conditions were significantly more efficient than in the one-depth condition (34 vs. 49ms/item). Perfect guidance would predict that two-depth RTxSetSize slopes should be half of the one-depth slopes. However, they were not that shallow. In Experiment 2, placeholders were presented in a cloud of 12 possible depths. Observers were cued toward the front, back, or middle of the depth cloud or no cue was given. The cue was probabilistic, meaning that a front cue indicated that the cue was most likely in the closest depth plane

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with lower probabilities at further depth planes. With these more heterogeneous displays, no benefits of prior knowledge of depth were observed. In a control, we confirmed that guidance by color works with our paradigm. Depth guidance works, but may be limited to near and far.

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23.3044 Into the Woods: Characterizing and Training Detection of Camouflaged Targets in Natural Scenes Dawn Sarno[1](dawn.sarno@knights.ucf.edu), Alyssa Hess[1], Joanna Lewis[1], Ada Mishler[1], Corey Bohil[1], Arthur Kramer[2], Mark Neider[1]; [1]Department of Psychology, College of Sciences, University of Central Florida, [2]Departments of Psychology and Engineering, Colleges of Science and Engineering, Northeastern University

Search performance has been shown to decline as target-background similarity increases (Wolfe, Oliva, Horowitz, Butcher, & Bompas, 2002). For some tasks, such as searching for a camouflaged enemy, this decrement in performance can mean life or death. Previous research has suggested that performance on these difficult search tasks can be improved through training (Hess, Wismer, Bohil, & Neider, 2016) and, importantly, this training has been found to transfer to novel stimuli (Neider, Ang, Voss, Carbonari, & Kramer, 2013). The goal of the present study was to develop a training intervention to improve detection of camouflaged targets in natural scenes and engender transfer to untrained targets and backgrounds. The training task consisted of searching for camouflaged targets derived from distorted patches of a wooded scene. Following training, transfer to new background classes was assessed utilizing novel wooded and urban scenes; transfer to new target classes was assessed with three novel target types: blur, lens flare, and geometric. Participants were assigned to one of three training groups (adaptive, massed, or control) and trained over 14, one-hour sessions. In the adaptive group, target difficulty varied on a trial-to-trial basis depending on performance; the massed group received increasingly more difficult targets as they progressed through the training sessions. Following training, both training groups showed evidence of transfer of training to novel wooded scenes compared to the control group, with the adaptive group showing the strongest evidence of transfer (average 1.5s decrease in response times, 7% increase in accuracy). The adaptive group also demonstrated transfer of training to several novel target classes. Our findings suggest that adaptively training participants to detect camouflaged targets in natural scenes can engender transfer of training to untrained background and target types.

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23.3045 When does visual search move on?: Using the color wheel to measure the dynamics of foraging search Anna Kosovicheva[1](a-kosov@neu.edu), Joseph Feffer[2], Abla Alaoui Soce[3], Matthew Cain[3,5], Jeremy Wolfe[3,4]; [1]Department of Psychology, Northeastern University, [2]State College Area High School, [3]Brigham and Women's Hospital, [4]Harvard Medical School, [5]U.S. Army Natick Soldier RD&E Center

When foraging for multiple instances of a visual target, can observers begin to search for the next item before collecting the current target or must they complete the current search first? To answer this question, we examined the temporal dynamics of foraging search using a novel dynamic color technique. Observers searched for 2–16 Ts among 9–23 Ls while all items continuously varied independently in color. The trial terminated after a pseudorandom number of targets had been clicked. At that point, observers were shown a color response palette and asked to report either the color of the "Current" target they had just clicked or the "Next" target they intended to click. The difference between the observers' color response and the actual color of the item at the end of the trial gives an estimate of the time (relative to the end of the trial) when they found the target. If observers were guessing, color distributions would be uniformly randomly distributed. However, distributions for Current and Next trials were narrower than those expected by random guesses, indicating that observers were able to report the color of the Next item on some proportion of the trials. Observers' color responses were also consistent with sequential acquisition of the targets. Average responses for Current targets corresponded to colors shown 330 ms before the end of the trial, while average responses for Next targets occurred 174 ms before the end of the trial. As targets become sparser, it takes longer to find the Next target and, thus, reports of the color and location of the Next item become increasingly random since the next item has not been found. The results show that observers are actively searching for and finding the Next target before they finish collecting the Current target.

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23.3046 Category supersedes identity in visual search: Attentional templates reflect participants' category knowledge in both item and set searches Brianna McGee[1](bmcge002@ucr.edu), Chelsea Echiverri[1], Benjamin Zinszer[2], Rachel Wu[1]; [1]University of California, Riverside, [2]University of Rochester

Prior research has shown that category search is similar to 1-item search (as measured by the N2pc ERP marker of attentional selection) because items in a category can be grouped into one attentional template. The present study investigated whether the perceived size of a familiar category impacts the attentional template used when searching for a category or specific items from that category. Critically, the perceived size of the categories was based on prior knowledge, rather than the experimental stimuli. We presented participants with sixteen items: eight from a smaller category (social media logos) and eight from a larger category (manufacturing company logos). We predicted that search for smaller categories would rely on a better-defined attentional template compared to larger companies, and therefore produce a larger N2pc. Twenty adult participants completed four search tasks: Search 1) specific social media logo (e.g., Facebook); Search 2) specific manufacturing logo (e.g., Xbox); Search 3) any social media logo; Search 4) any manufacturing logo. Neither reaction time nor accuracy differed between searches for social media logos or manufacturing logos, and familiarity measures showed that both categories were equally familiar to the participants. However, only searches in the social media category (for either a specific item or any item from the category) produced a significant N2pc. No N2pc was found in either item or category search for manufacturing logos. Our results show that participants' knowledge about a category's size influences the way they search for both a specific item from the category and the whole category.

23.3047 Modeling categorical search guidance using a convolutional neural network designed after the ventral visual pathway Gregory Zelinsky[1](Gregory.Zelinsky@stonybrook.edu), Chen-Ping Yu[2]; [1]Departments of Psychology and Computer Science, Stony Brook University, [2]Department of Psychology, Harvard University

Category-consistent features (CCFs) are those features occurring both frequently and consistently across the exemplars of an object category. Recently, we showed that a CCF-based generative model captured the overt attentional guidance of people searching for name-cued target categories from a 68-category subordinate/basic/superordinate-level hierarchy (Yu, Maxfield, & Zelinsky, 2016, Psychological Science). Here we extend this work by selecting CCFs for the same 68 target categories using an 8-layer Convolutional Neural Network (CNN) designed to reflect areas, receptive field (kernel) sizes, and bypass connections in the primate ventral stream (VsNet). We replicated our previously-reported finding that the number of CCFs, averaged over categories at each hierarchical level, explains the subordinate-level guidance advantage observed in gaze time-to-target. However, we now show stronger guidance to individual categories for which more CNN-CCFs were extracted ($r=0.29$, $p=0.01$). We also found that CCFs extracted from VsNet's V1-V2 layers were most important for guidance to subordinate-cued targets (police cars); CCFs from TEO-V4 and V4-TE contributed most to guidance at the basic (car) and superordinate (vehicle) levels, respectively. This pattern suggests a broad coding of priority throughout the ventral stream that varies with cue specificity; early visual areas contribute more to subordinate-level guidance while less specific cues engage later areas coding representative parts of the target category. Converging evidence for this suggestion was obtained by finding the image patches eliciting the strongest filter responses and showing that these units from areas V4 and higher had receptive fields tuned to highly category-specific parts (police car sirens). VsNet also better captured observed attentional guidance behavior, and achieved higher classification accuracy, than comparable CNN models (AlexNet, Deep-HMAX), despite VsNet having fewer convolutional filters. We conclude that CCFs are important for explaining search guidance, and that the best model for extracting CCFs is a deep neural network inspired by the primate visual system.

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23.3048 How the Heck Did I Miss That? How to use the hybrid search paradigm to study "incidental finding" errors in radiology.

Jeremy Wolfe[1,2](wolfe@search.bwh.harvard.edu), Abla Alaoui Soce[1]; [1]Brigham and Women's Hospital, [2]Harvard Medical School

When radiologists perform one task (e.g. Does this patient have pneumonia?), they are also expected to search for "incidental findings" that might be clinically significant (e.g. signs of lung cancer). Unfortunately, these incidental findings are missed at rates higher than is desirable. Moreover, the same lesion that would be found if it were the object of search, can be missed when it is an incidental finding. To develop techniques to address this problem, we have designed a hybrid search analog task that can be used with non-experts. In hybrid search, observers look for an instance of any of several candidate targets held in memory. Reaction time (RT) increases linearly with the visual set size and linearly with the log of the number of targets held in memory. The same pattern is seen with search for categorical targets (e.g. find any cat, car, coin, or cookie), but these targets produce longer RTs. To simulate the incidental finding situation, observers search for any of three specific and three categorical targets. Specific targets are the analog of the radiologist's specific task. Categorical targets are the analog of the incidental findings. They are known to the observer but less well-defined than the specific targets. When categorical and specific targets are mixed within a block, observers miss more than twice as many categorical targets as they do specific targets. Observers miss fewer categorical targets if all targets in a block are categorical. Observers miss the fewest targets when all were specific. In a mixed block with 4X as many specific targets as categorical targets, the categorical target miss rate becomes very large (38%), mimicking the pattern of incidental finding errors in radiology. Given this 'model system', we can test interventions that could reduce the incidental error rate in the lab and in the clinic.

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23.3049 "Deep" Visual Patterns Are Informative to Practicing Radiologists in Mammograms in Diagnostic Tasks

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"Deep Learning" is a form of perceptual learning in which the trainee learns to perform a given task by learning the informative, often abstract, statistical patterns in the data from a relatively large set of labeled examples. We have previously reported that, using deep learning, naïve, non-professional human observers can be trained to detect camouflaged objects in natural scenes, or anomalies in radiological images (Chen and Hegdé, Psychol Sci 2014; Hegdé, J Vis 2014). By systematically manipulating the deep visual patterns (e.g., principal components [PCs]) using image synthesis algorithms, we have identified the patterns that such non-professional 'experts' use in detecting cancers in screening mammograms. But it is not known whether or to what extent practicing radiologists can or do use the same patterns. To help address this issue, we tested practicing radiologists (N = 9; 3 mammography specialists) under comparable conditions. Briefly, either original mammograms or synthesized counterparts that were missing 0 to 2 of the previously characterized PCs were viewed ad libitum one per trial. Depending on the trial, subjects indicated whether the mammogram contained a cancer (detection task), or whether the image was original or synthesized (discrimination task). Subjects were unable to discriminate original vs. synthesized images when the latter contained all PCs ($d' = 0.38$, $p > 0.05$), indicating that the two sets of images were mutually perceptually metameric. In the detection task, the performance of the radiologists covaried with the cumulative eigenvalue of the PCs in the image and with that of the non-professional subjects (two-way ANCOVA, eigenvalue x training mode; $p < 0.05$ for both factors and interaction). Together, our results indicate that at least some of the visual patterns used by professionally trained radiologists are the same as that learned and used by non-professionals trained in the laboratory.

Acknowledgement: This study was supported by the U. S. Army Research Office grants W911NF-11-1-0105 and W911NF-15-1-0311 to Jay Hegdé.

23.3050 Predicting airport screening officers' visual search competency with a rapid assessment

Stephen Mitroff[1](mitroff@gwu.edu), Justin Ericson[1], Benjamin Sharpe[2]; [1]The George Washington University, [2]Kedlin Company

Visual search is a vital cognitive ability for a variety of professions, including airport security, radiology, and the military. Given the importance of such professions, it is necessary maximize performance, and one means to do so is to select individuals based upon their visual search competency. Recent work has suggested that it is possible to quickly classify individuals as strong or weak visual searchers (Ericson, Kravitz, & Mitroff, Psychonomic Society 2016); demonstrating that those who started out faster and more accurate were more likely to have superior performance later in the task. A critical question is whether it is possible to predict search competency within a professional search environment. The current study examined whether a relatively quick visual search task could predict professional searchers' actual on-job performance. Over 600 professional searchers from the USA Transportation Security Administration (TSA) completed an approximately 10-minute assessment on a tablet-based XRAY simulator (derived from Airport Scanner; Kedlin Co.). The assessment contained 72 trials that were simulated XRAY images of bags. Targets (0 or 1 per trial) were drawn from a set of 20 prohibited items, and distractors (5 to 15 per trial) were taken from a set of 100 allowed items. Participants searched for prohibited items and tapped on them with their finger. Two tutorials had to be successfully complete prior to the assessment. Performance on the assessment significantly related to three on-job measures of performance for the TSA officers: (1) detecting simulated threat items projected into actual carry-on bags, (2) detecting real threat items covertly introduced into the checkpoint, and (3) an annual proficiency exam. These findings suggest that it may be possible to quickly identify potential hires based on their core visual search competency, which could provide organizations the ability to make new hires and assess their current workforce.

Acknowledgement: US Transportation Security Administration

VISUAL MEMORY: LONG TERM AND WORKING

Saturday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4001 Context transitions modulate perceptual serial dependence

Anastasia Kiyonaga[1](kiyonaga@berkeley.edu), Mauro Manassi[1], Mark D'Esposito[1], David Whitney[1]; [1]Helen Wills Neuroscience Institute

Serial dependence in perception describes when visual stimuli appear more similar to recently-attended stimuli than they truly are. By smoothing perception over the ever-changing image on the retina, this bias is thought to stabilize our visual experience from one moment to the next. Although this perceptual continuity is generally helpful, it fundamentally reflects a misapprehension of the current stimulus, and could therefore interfere with processing when the previous information is no longer relevant to current goals (i.e., proactive interference). If serial dependence between successive perceptual instances were flexible and adaptive, therefore, it should be reduced when environmental cues trigger the segmentation of visual episodes. Event boundaries (i.e., transitions to a new episode or context) are thought to update one's goal state in working memory, and may thereby signal that the upcoming information should be segregated from what came before. Accordingly, we expect a stable context to promote serial dependence in perception, whereas a context shift should flush the lingering trace of recent perception from memory, and curtail its influence on current processing. We tested this hypothesis by periodically changing the background color (i.e., context) during a continuous series of orientation judgments. On each trial, participants saw a randomly-oriented grating, then adjusted a response bar to match their perceived orientation of the stimulus. Across all trials, orientation responses were attracted toward the orientation from the previous trial. On the first trial in a new context, however, this serial dependence was eliminated, suggesting that the (typically attractive) previous trial information was purged at the start of a new visual episode. In contrast, all subsequent trials in a given context showed significant serial dependence. These data suggest that context transitions can update goal settings to dampen the bias toward recently-attended stimuli when it may no longer serve current goals.

23.4002 **Evidence for sequential access in visual long-term memory**

Inder Singh[1](inders@bu.edu), Aude Oliva[2], Marc Howard[1]; [1]Center for Memory and Brain, Boston University, [2]CSAIL, Massachusetts Institute of Technology

One of the most well-known results in recognition memory tasks is that the response time increases and accuracy reduces with an increase in the lag of the item and the probe. These effects are usually explained by changes in memory strength with lag. Models of memory that include a temporal dimension allow for a mechanism of sequential access. We used a continuous recognition paradigm with highly memorable pictures to mitigate changes in accuracy and enable a detailed examination of the effect of recency on retrieval dynamics across three experiments. The recency at which the pictures were repeated ranged over more than two orders of magnitude from immediate repetitions after a few seconds to tens of minutes. Analysis of the RT distributions showed that the time at which memories became accessible changed with the recency of the probe item. Despite changes in accuracy across the three experiments, we see a consistent slope of the first decile of the RT distributions with logarithm of the intervening lag. The linear trend in RT on a log scale suggests an underlying compressed temporal dimension. Analyses of RT distributions showed that the time to initiate memory access to varies with log(lag). Additional analyses revealed that this effect was not attributable to an effect of immediate repetitions nor to increased processing fluency of the probe. These results suggest that visual memories can be accessed by sequentially scanning along a compressed temporal representation of the past. The form of the compression is closely analogous to the compression associated with cortical magnification in vision.

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23.4003 **Different Limits on Fidelity in Visual Working Memory and Visual Long Term Memory**

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How detailed are long-term memory (LTM) representations as compared to those of working memory (WM)? Recently, Brady et al. (2013) suggested that both types of memory are constrained by the same bound on fidelity, after which the memory representation is lost. In their experiments, however, WM performance may have been contaminated with LTM representations. Here, we aimed to replicate their findings, while tapping a purer measure of WM. In addition, we examined whether a representation of an item can exist alongside the absence of color information. Participants were presented with colored real-life objects and were asked to remember both the items and their color. At test, participants judged whether the objects, presented in grey, had previously appeared (item memory) and then chose their color from a continuous-color wheel (color memory). This procedure allowed us to examine the memory of an item separately from the memory of its corresponding color, in a within-subject design. In the WM condition, participants had three seconds to encode three colored objects, after which they performed the item- and color-memory tasks for only a single object out of the three. In the LTM condition, participants were presented with hundreds of items, one at a time for three seconds each. They were subsequently tested for item and color memory. We calculated the variability of internal representations of color (fidelity) and the probability of forgetting an object's color. In replication of Brady et al. (2013), the probability of guessing in LTM was found to be higher than in WM. However, the critical analysis of fidelity revealed significantly better fidelity for WM. We also found that items can be remembered while their color is lost, rendering item and color information to be partly independent. We discuss the theoretical implications of different boundaries of WM and LTM.

23.4004 **Enhanced perceptual processing of visual context benefits later memory**

Megan deBettencourt[1,2](debetten@uchicago.edu), Nicholas Turk-Browne[3,4], Kenneth Norman[3,4]; [1]Institute for Mind and Biology, University of Chicago, [2]Department of Psychology, University of Chicago, [3]Princeton Neuroscience Institute, Princeton University, [4]Department of Psychology, Princeton University

Fluctuations in attention affect task performance in the moment, but can also have long-lasting consequences by influencing memory formation. These effects are typically studied by manipulating whether to-be-remembered objects or words are selectively attended during encoding. However, a key determinant of memory is the temporal context in which stimuli are embedded, not just the individual stimuli themselves. Here we examine how attention to temporal context impacts subsequent memory. Participants in two fMRI experiments completed multiple runs of a memory-encoding task. In each run, they studied lists of sequentially presented words for a later test. Between words, participants were rapidly presented with a series of photographs from a single visual category, either faces or scenes. These photographs served as the temporal context, and were not themselves tested for memory. At the end of the run, participants were asked to recall as many words as possible from one of the lists. We trained a multivariate pattern classifier to decode the two possible contexts (face versus scene) from an independent localizer task with no words. Applying this classifier to the memory-encoding runs allowed us to measure the perceptual processing of the temporal context for a given list. As a manipulation check, we were able to decode the visual category of the interleaved context photographs when collapsing across lists. Critically, list-wise variance in this decoding related to list-wise variance in the number of words later recalled. Moreover, within lists, there was more classifier evidence for the category of the context surrounding, and even preceding, words that were later remembered versus forgotten. Altogether, these findings suggest that enhanced contextual processing may be one mechanism through which attention can boost memory formation.

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23.4005 **The impact of mnemonic interference on memory for visual form**

Aedan Li[1](aedanyue.li@mail.utoronto.ca), Celia Fidalgo[1], Andy Lee[1,2], Morgan Barense[1,2]; [1]Department of Psychology, University of Toronto, [2]Rotman Research Institute, Baycrest

How does interference impact memory? Previous work found that different types of distracting information can differentially alter how visual representations are forgotten. In addition, a recent series of experiments found that highly dissimilar interfering items erase the contents of memory, while highly similar and variable interfering items blur memory representations. Though these effects have been shown for color memory, it is unclear if they extend to other object features such as shape. Here, we used a novel "Shape Wheel" to assess how different kinds of interference would impact shape memory. On this wheel, 2D line drawings were morphed together to create an array of 360 shapes, corresponding to 360 degrees on a circle. Participants were asked to remember a shape sampled from this wheel, then were shown interfering shapes that were either perceptually similar to the studied shape, perceptually dissimilar from the studied shape, perceptually variable, or scrambled shapes (baseline condition). We used a mixture model to measure the probability that the item is stored in memory, defined as accuracy, as well as the level of detail of that representation, defined as precision. We found that when interfering shapes were similar to the studied item, a numerical but non-significant benefit to memory accuracy was observed. However, when interfering shapes were dissimilar to the studied item, accuracy was reduced. In contrast, memory precision was reduced only when interfering shapes were similar or perceptually variable. These findings extend previous results by demonstrating the differential effects of interference for isolated feature-level shape information. Visually dissimilar interference erases memory representations, while visually variable and highly similar interfering items tended to blur shape representations. As the impact of interference was consistent across studies, these findings may offer a set of general principles regarding how interference impacts high-level object representations and all features therein.

23.4006 **Does an unexpected task reset the contents of visual working memory?**

Garrett Swan[1](gsp.swan@gmail.com), Brad Wyble[1], Hui Chen[2]; [1]Department of Psychology, College of Liberal Arts, Pennsylvania State University, [2]Department of Psychology, Zhejiang University

It is well known that visual information can be held in memory while performing different tasks concurrently, such as remembering a color during a separate visual search task. However, it is not clear whether we can maintain this information in the face of immediate unexpected tasks, such as a surprise question. This question is relevant to our general understanding of

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visual working memory and attention and is also relevant for experimental paradigms utilizing surprise test methodologies. When considering the results of experiments with unexpected questions, it is especially important to determine if an inability to report information is due to the reorientation to a new task imposed by the surprise question. To answer this question, we ran two experiments where the instructions unexpectedly switched from recognition to recall in a surprise trial. Half of the participants were asked to report the same attribute (Exp1 = Identity, Exp2 = Color) of a target stimulus in both pre-surprise and post-surprise trials, while for the other half, the reported attribute switched from identity to color or vice versa. Importantly, all participants had to read an unexpected set of instructions and respond differently on the surprise trial. A decline in accuracy on the surprise trial compared to the first control trial was only observed in the different-attribute groups, but not in the same-attribute groups. Accuracy on the surprise trial was also higher for the same-attribute groups than the different-attribute groups. Furthermore, there was no difference in reaction time on the surprise trial between the two groups. These results suggest that information participants expected to report can survive an encounter with an unexpected task. The implication is that failures to report information on a surprise trial in many experiments reflect genuine differences in memory encoding, rather than forgetting or overwriting induced by the surprise question.

23.4007 **Are memorable images easier to categorize rapidly?** Lore Goetschalckx[1](lore.goetschalckx@kuleuven.be), Steven Vanmarcke[1], Pieter Moors[1], Johan Wagemans[1]; [1]Laboratory of Experimental Psychology, Brain and Cognition, KU Leuven

Some images we see stick in mind, while others fade. Recent studies of visual memory have found remarkable levels of consistency for this inter-item variability across observers (e.g., Isola 2011), suggesting that memorability can be considered an intrinsic image property. However, the visual features underlying memorability are not yet well understood. Investigating the relation between image memorability and inter-item variability in other visual tasks can provide more insight. Here, we asked whether an image that is easier to process and categorize is also more memorable. We used a rapid-scene categorization task and assessed whether there are consistent differences in difficulty between images in this task (defined as "categorizability") and whether they correlate with memorability. We selected 14 scene categories and 44 images per category from a set previously quantified on memorability (Bylinskii 2015). Per trial, participants saw an image for a duration of 32 ms, followed by a mask of 80 ms. Next, a category label appeared on screen and the task was to indicate whether the label matched the image. For each participant, a random half of the scenes was presented as signal trials (i.e., label matches image), the other half as no-signal trials. For signal trials, we collected on average 79 responses per image. An image's categorizability score was calculated as the proportion of correct responses on signal trials. The average categorizability score per category varied between .55 and .89. Thus, given the task context, some categories were considerably easier than others. For most categories, consistency scores were high (mean split-half Spearman's rho up to .90), suggesting that categorizability is an intrinsic image property too. However, the predicted positive correlation between categorizability and memorability was not observed. This suggests that the ease with which an image can be categorized relies on features distinct from those involved in memorability.

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23.4008 **Resource scarcity impairs visual online detection and prospective memory** Brandon Tomm[1](brandon.tomm@psych.ubc.ca), Jiaying Zhao[1,2]; [1]Department of Psychology, University of British Columbia, [2]Institute for Resources, Environment and Sustainability

Operating under limited resources (e.g., money, time) poses significant demands on the cognitive system. Scarcity induces attentional trade-offs of information in the environment, which can impact memory encoding. In three experiments (N=227) we demonstrate that people under time scarcity failed to detect time-saving cues as they occur in the environment, suggesting that scarcity impairs the ability to detect online cues. These time-saving cues, if noticed, would have saved more time for the time poor participants, alleviating the condition of scarcity. A follow-up experiment showed that the visuospatial proximity of the time-saving cues to the focal task determined successful detection of the time-saving cues, suggesting that the online detection errors can be explained by spatial attention on the task at hand. Thus, time scarcity may cause attentional trade-offs whereby attention is focused on the task at hand, while ironically, other beneficial information is neglected as it occurs in the environment. We also demonstrate that people under time scarcity were more likely to forget previous instructions to execute future actions, suggesting that scarcity causes prospective memory errors. Ironically, the time poor participants failed to remember previous instructions which, if followed, would have saved them time. These experiments show that scarcity impairs the online detection of beneficial information in the environment, as well as the execution of prospective memory cues. Failures of prospective memory and online detection are particularly problematic because they cause forgetting and neglect of beneficial information, perpetuating the condition of scarcity. The current studies provide a new cognitive account for the counterproductive behaviors in individuals under resource scarcity, and have implications for interventions to reduce neglect and forgetting in the poor.

23.4009 **Suppressing visual representations in long-term memory with recognition** Ashleigh Maxcey[1](ammaxcey@gmail.com); [1]The Ohio State University

In this presentation, I will discuss a paradigm we have developed to look at recognition-induced forgetting of visual objects. Recognition-induced forgetting occurs when practice recognizing an object, from a group objects learned at the same time, leads to worse memory for objects from that group that were not practiced. This forgetting effect is commonly accompanied by improved memory for practiced objects. We have shown that recognition-induced forgetting is not an artifact of category-based set size. I will discuss our developmental work showing this forgetting effect comes online by 6 years of age without a memory benefit for practiced objects until 9 years of age. Further, the forgetting appears to remain robust with healthy aging in samples of older adults, without the benefit for practiced objects shown in young adults but accompanied by a decrease in intrusion errors. I will conclude by discussing our use of this paradigm to understand how this forgetting phenomenon operates on temporally clustered objects and stimuli of expertise, as well as our technique of using cathodal transcranial direct-current stimulation to DLPFC to examine the role of inhibitory mechanisms in this forgetting phenomenon.

23.4010 **Sequential whole-report reveals different states in visual working memory** Benjamin Peters[1](peters@med.uni-frankfurt.de), Benjamin Rahm[2], Stefan Czoschke[1], Catherine Barnes[1], Jochen Kaiser[1], Christoph Bledowski[1]; [1]Institute of Medical Psychology, Goethe-University, Frankfurt am Main, Germany, [2]Medical Psychology and Medical Sociology, Albert-Ludwigs-University, Freiburg, Germany

Working memory (WM) provides rapid and flexible access to a limited amount of information in the service of ongoing tasks. Studies of visual WM usually involve the encoding and retention of multiple items, while probing a single item only. Little is therefore known about how well multiple items can be reported from visual WM. Here we asked participants to successively report each of up to eight simultaneously encoded Gabor patch orientations from WM. Report order was externally cued, and stimulus orientations had to be reproduced on a continuous dimension. Participants were able to sequentially report items from WM with an above-chance precision even at high set sizes. Importantly, we observed that precision varied systematically with report order: It dropped steeply from the first to the second report but decreased only slightly thereafter. This trajectory of precision was better captured by a discontinuous rather than an exponential function, suggesting that items were reported from different states in visual WM. Additional experiments showed that the steep drop in precision between the first and subsequent reports could not be explained by a retro-cue that selectively protected fragile visual WM representations for the first reported item, the longer retention interval for later reported items, or the visual interference by the first report. Instead, the drop in precision disappeared when participants performed an interfering task that mimicked the executive demands of the report procedure after the retention interval and prior to the first report. The present study provided the hitherto missing initial characterization of sequential reports from visual WM. Taken together, these results suggest that a sequential whole-report reveals qualitatively different states in visual WM that may differ in the degree of dependence on executive functions.

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23.4011 **Surface and boundary organization of objects influences visual short-term memory performance** Benjamin McDunn[1](bmcdunn@uga.edu), James Brown[1]; [1]University of Georgia

Visual features of an object can be properties of either its surface (such as color or texture) or its boundary (such as shape or size). Previous visual short-term memory studies have focused on the importance of object number in determining capacity limits, but an "object" might have any number of distinct surfaces and boundary contours. In the current study, we explore how the organization of surfaces and boundaries that indicate two task-relevant features can influence memory performance. In Experiment 1, memory for two task-relevant features (color and orientation) was tested in four display conditions utilizing different surface and boundary organizations for the object stimuli. Experiment 2 tested the same four display conditions using two boundary features, size and shape, as the task-relevant features. Both experiments were conducted using both a full probe trial-type, where all studied objects reappeared at test, and a partial probe trial-type, where only one object reappeared at test. The combination of display conditions and probe trial-types allow us to distinguish effects from both local proximity of the features and utilization of the global spatial layout of the display. The results of Experiments 1 and 2 show significant differences depending on display type that interact with probe type. Interestingly, the results suggest the differences between surface and boundary organizations of the stimuli were mediated by differences in the utilization of either local proximity of the features or the global spatial layout of the display. This finding suggests some effects of object status on memory performance observed in previous studies may be mediated by how effectively these proximity cues can be utilized by participants.

23.4012 **The Role of Memory Uncertainty in Change Localization** Aspen Yoo[1](aspen.yoo@nyu.edu), Luigi Acerbi[1,2], Wei Ji Ma[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

In many perceptual tasks, humans near-optimally use sensory uncertainty information in their decisions. It is unknown whether they do so in decisions based on visual working memory (VWM). Some circumstantial evidence is available: humans' confidence reports are positively correlated with their errors in a delayed-estimation task (Rademaker et al., 2012), and humans near-optimally integrate current knowledge of uncertainty with working memories (Keshvari et al., 2012). However, it is unclear whether people accurately store uncertainty information in VWM and use it in a subsequent decision. To investigate this, we collected data in two change localization tasks with variable stimulus reliability. Each trial consisted of a sample array of four Gabors, a delay, and a test array of four Gabors. Participants reported which of the four Gabors changed in orientation. In Task 1, we used two levels of contrast to manipulate memory uncertainty. In the sample array, the stimuli could be all high contrast, all low contrast, or two of each. In the test array, stimuli were either all high or all low contrast. In Task 2, we replicated this result with variable delay times (1 or 3 seconds) instead of variable contrast. We evaluated two models. The Optimal model assumes that observers know their memory uncertainty on a trial-to-trial and item-to-item basis and use this information to maximize performance. The Fixed model assumes observers do not use knowledge of their uncertainty, but assume that stimuli are equally uncertain. In both tasks, the Optimal model outperformed the Fixed model for three of four participants (: Task 1: M = 10.1, SEM = 6.9; Task 2: M = 9.3, SEM = 15.3). Moreover, the Optimal model provides good fits to the psychometric curves. These results provide preliminary evidence that humans maintain uncertainty information in VWM and use it in a subsequent decision.

23.4013 **Is location information lost from visual short-term memory?** Andra Mihali[1](alm652@nyu.edu), Wei Ji Ma[1]; [1]New York University

Visual short-term memory (VSTM) performance as a function of set size is well accounted for by noise corrupting the stimulus representation, with the amount of noise increasing with set size. It has been proposed that, in addition to this mechanism, there is also a loss of binding between feature and location information (Bays et al, 2009). An analysis of delayed-estimation data suggests that the prevalence of such binding errors is low (Van den Berg, Awh, and Ma, 2014), but this analysis was quite indirect. Here, we address the question of whether location information is maintained in VSTM with a more direct approach. 11 observers performed two VSTM-based tasks with arrays of 2,3,4 and 6 items: a target detection task (target present half of the time) and a target localization task (always one target). Any loss of location information would affect localization performance but not detection performance. Therefore, if we can jointly fit an optimal observer model with the same parameters to detection and localization, this would suggest that location information loss is minimal. Indeed, we were able to fit well the variable-precision encoding model jointly to the detection and localization data. These preliminary model fits suggest that location information is maintained in VSTM to a significant extent.

Acknowledgement: NIH

23.4014 **Attentional boost effect: Failure to replicate** Katherine Moen[1](kmoen1@lsu.edu), Stephanie Saltzmann[1], Melissa Beck[1]; [1]Psychology, Louisiana State University

Dual-task paradigms typically impair performance relative single-task paradigms. However, research on the attentional boost effect (ABE) suggests that dual-task performance is improved to that of single-task performance on critical trials (when a response is required). The response leads to improved memory for the simultaneously presented scene, relative to a single-task. Research suggests that responding to a subset of stimuli results in increased attention, leading the to better memory for the associated memory items. In an attempt to better understand the role of attention in the ABE, we measured eye movements during a typical ABE task. Therefore, the current study sought to replicate the ABE and document the pattern of eye movements associated with critical and non-critical trials. In three experiments, participants encoded real-world scenes with a circle in the center. Divided attention (DA) participants pressed a button when the circle was a non-prevalent color, and full attention (FA) participants ignored the circles. All participants completed a recognition memory test after a delay. Replicating previous ABE studies, Experiment 1 used a 1000ms encoding time and a two-alternative-forced-choice recognition test, Experiment 2 used 1000ms encoding time and a single-item recognition test, and Experiment 3 used a 500ms encoding time and a single-item recognition test. Behavioral results revealed no differences between FA and DA in the first two experiments and a DA impairment in Experiment 3. No ABE was observed in any of the three experiments. Across three experiments, dwell times during test were longer for the FA condition compared to DA condition. There were no differences during encoding, and no differences for critical versus non-critical trials. Overall, these experiments suggest that the ABE is not robust. The lack of an ABE is consistent with the lack of allocation of attention differences, as measured by eye movements, on critical versus non-critical trials.

23.4015 **Working Memory Capacity and Cognitive Filtering Predict Demand Avoidance.** Jeff Nador[1](jeff.nador@wright.edu), Brad Minnery[2], Matt Sherwood[2], Assaf Harel[1], Ion Juvina[1]; [1]Wright State University, [2]Wright State Research Institute

In general, optimization of task performance minimizes cognitive demand. For example, when participants can choose freely between task variants, they tend to select the one that minimizes cognitive demand (Kool et al., 2010). Here, we test whether the ability to filter irrelevant information during task performance will reduce cognitive processing demands. Previous research has shown that observers with higher visual working memory (VWM) capacity tend to be more efficient cognitive filterers (Vogel, McCollough & Machizawa, 2005). Consequently, we hypothesize that such demand avoidance arises from individual differences in VWM capacity. To test this hypothesis, we collected psychophysical and electrophysiological measures of VWM capacity and cognitive filtering in a sample of 22 observers. We then correlated these with independent psychophysical measures of demand avoidance. We found that observers with higher VWM capacity tended to select the less demanding of two task alternatives, and that this occurred because filtering irrelevant information increased their sensitivity to our covert demand manipulation. Moreover, reaction times increased significantly when a given trial's instructions switched with respect to the preceding trial's, and this increase tended to be larger among those with greater cognitive filtering ability. Taken together, our results suggest that working memory capacity and cognitive filtering ability contribute to individual differences in demand avoidance. Inefficient cognitive filterers tend to process more irrelevant information and are therefore less sensitive to covert variations in demand. Efficient filterers, on the other hand, can suc-

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cessfully ignore irrelevant information, and are therefore more sensitive. As such, we surmise that individual differences in visual working memory capacity and cognitive filtering predict demand avoidance.

Acknowledgement: Office of Naval Research

23.4016 **Dissociable biases in orientation recall: The oblique effect follows retinal coordinates, while repulsion from cardinal follows real-world coordinates.** Rosanne Rademaker[1](rosanne.rademaker@gmail.com), Chaipat Chunharas[1], Pascal Mamassian[2], John Serences[1]; [1]Psychology Department, University of California San Diego, San Diego, USA, [2]Laboratoire des Systèmes Perceptifs, Ecole Normale Supérieure, Paris, France

Systematic biases emerge when people report an orientation from memory after a brief delay. One such bias is the classic oblique effect, with smaller replication errors for targets presented at cardinal compared to oblique orientations. A second known bias is a repulsion away from the cardinal axes, with responses to targets near vertical and horizontal exaggerated to lie even further away from those axes. Here we wanted to test the origins of these biases. Twelve participants were presented with randomly oriented gratings (between 1–180º in 3º steps) on each trial for 100 ms. After a 1.5 s delay period a response probe appeared and participants replicated the target orientation using the mouse. Critically, on half of the trials a rotating chinrest tilted the head of participants 45º from upright – with tilt direction counterbalanced across participants. Participants switched between upright and tilted head positions every 60 trials, and 1800 trials per tilt position were collected over the course of several days. Data show that the classic oblique effect is tied to a retinal coordinate frame, with better resolution for targets presented at orientations that are cardinal relative to the head, irrespective of its tilt. However, the repulsion from cardinal remained tied to real world vertical and horizontal. We hypothesize that while the classical oblique effect is driven by retinal and cortical factors determined during visual development (such as the over-representation of cardinal orientations in visual cortex), the second 'repulsion' bias is due to a higher-level decisional component whereby representations are cropped relative to real-world cardinal coordinates.

Visual Memory: Working memory

Saturday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4017 **Saccades Smear Spatial Working Memory** Matthew Peterson[1,2,3](mpeters2@gmu.edu), Shane Kelley[1], Eric Blumberg[1]; [1]Human Factors and Applied Cognition, George Mason University, [2]Cognitive and Behavioral Neuroscience Program, George Mason University, [3]Neuroscience Interdisciplinary Program, George Mason University

We took advantage of saccadic remapping to test whether eye movements and spatial working memory (SWM) share a common spatial representing system. If SWM, perception, and saccades share the same spatial representation system, then multiple saccades along the same axis should lead to representationql errors along that axis due to the increased potential for errors from multiple remappings. Subjects performed a spatial change detection task (6 sessions). During the retention interval, subjects detected whether an X (go) or O (no-go) appeared. Depending on the session, the X or O was either located centrally (no-shift), peripherally and identified using covert attention (covert), or peripherally and identified using a saccade. For the change detection task, when a change occurred, an item moved either in the vertical or horizontal direction (0.56°-3.4°). For Experiment 1, saccades and covert shifts occurred along the horizontal axis, and in Experiment 2 shifts were made along the vertical axis. For both experiments, memory accuracy was highest for the no-shift condition, lower for the covert condition, and lowest for the saccade condition (Lawrence et al., 2004). Gaussian PDFs were fit to the memory data, with standard deviation (precision), guessing, and bias as parameters. None of the tasks had a significant effect on bias or guessing. However, in both experiments, a covert attention shift led to a loss of memory precision compared to the no-shift condition, and this loss was equal in both the vertical and horizontal planes. Importantly, in both experiments saccades had an additional effect beyond covert attention: there was an additional loss of precision for changes that occurred in the same plane as the saccade as opposed to changes that occurred in the orthogonal plane. This supports our hypothesis that saccade driven remapping impacts the precision of SWM – saccades smeared SWM.

23.4018 **The effects of content-dependent competition on working memory capacity limits** Jason Scimeca[1](jscimeca@berkeley.edu), Jacob Miller[1], Mark D'Esposito[1]; [1]Helen Wills Neuroscience Intitute, University of California, Berkeley

Both visual attention and working memory (WM) are marked by severe capacity limits. The biased-competition model (Desimone & Duncan, 1995) proposes that capacity limits in visual attention arise because simultaneously perceived stimuli compete for neural representation in sensory cortex. Sensory recruitment models of WM (D'Esposito, 2007; Postle, 2006) argue that information in WM is maintained in sensory cortex. The competitive map framework links these models by proposing that capacity limits in attention and WM arise from competition in content-dependent cortical maps (Franconeri et al., 2013). A recent study demonstrated that this map framework can explain visual processing limits for simultaneously presented items drawn from either the same or different categories (e.g. two faces/two scenes or four faces; Cohen et al., 2014). Here we examine whether the map framework can explain capacity limits in WM. To prevent competition at perception, four items were sequentially presented and then maintained in WM for 10 seconds. Across several categories (faces/bodies/scenes), WM capacity is higher when items are drawn from separate categories versus a single category. This is consistent with lower across-category versus within-category competition, supporting the role of content-dependent competition in WM capacity limits independent of perceptual competition. Furthermore, we used fMRI and a forward modeling approach (Brouwer & Heeger, 2011) to assess the nature of competition that occurs within WM. Using multivoxel patterns in sensory cortex recorded on low-load (load-2) same-category trials, we trained a model to project fMRI activity into a representational space consisting of content-dependent channels (e.g. a face channel and a scene channel). We then invert the model to reconstruct channel amplitudes based on data from load-4 same-category and mixed-category trials. The amplitude of the relevant channel predicts behavioral accuracy across trials, and these amplitudes are higher on mixed-category versus same-category trials, consistent with reduced cortical competition across content-dependent channels.

23.4019 **The Functional Limit in Visual Working Memory Storage: The Tale Is In The Tail** Marcus Cappiello[1](mcapp001@ucr.edu), Weiwei Zhang[1]; [1]Department of Psychology, University of California, Riverside

Although working memory plays a significant role in a wide range of cognitive domains, its storage capacity is highly limited. The nature of this limit in visual working memory (VWM) has been the subject of considerable controversy. The discrete-slot model attributes the bottleneck in VWM storage to capacity (i.e., a limited number of discrete slots). In contrast, the variable precision model replaces the capacity limit with variable mnemonic precision in that the variance in precision could produce extremely low precision that behaviorally resembles random memory responses. One common misconception about the discrete-slot model assumes no variance in mnemonic precision across items and trials, potentially leading to the model's poor performance in comparison to the variable precision model. More importantly, the most fundamental difference between the two models is the presence (discrete-slot model) or absence (variable precision model) of guessing for a large number of to-be-remembered items (i.e. a capacity limit). The present study thus adopted four approaches to establish this discrete nature of VWM storage. First, the slot model with variability sufficiently accounted for residual errors in model fits. Second, the slot model outperformed the variable precision model at large memory set sizes when capacity constrained recall performance more than precision. Thirdly, the variable precision model produced increasing proportion of extremely low precision trials that are indistinguishable from guessing (and hence functionally equivalent to capacity) over memory set sizes. Lastly, non-parametric modeling of recall data showed strong evidence for two discrete clustering of precision in the true underlying distribution (one for guessing and the other for graded memory representation). Together these results provide strong support for the slot model of VWM storage limit.

23.4020 **When shorter delays lead to worse memories: Taking attention away from visual working memory temporarily makes it more vulnerable to test interference.**
Benchi Wang[1](wangbenchi.swift@gmail.com), Jan Theeuwes[1], Christian Olivers[1]; [1]Department of Experimental and Applied Psychology, Vrije Universiteit, Amsterdam, the Netherlands

Evidence shows that visual working memory (VWM) is strongly served by attentional mechanisms, whereas other evidence shows that VWM representations readily survive when attention is taken away. To reconcile these findings, we tested the hypothesis that directing attention away makes a memory representation vulnerable to interference from the test pattern, but only temporarily so. When given sufficient time, the robustness of VWM can be restored. In six experiments, participants remembered a single grating for a later memory test. In the crucial conditions, participants also performed a letter change detection task in between, during the delay period. Using various replications, Experiments 1-4 demonstrate, the effect predicted: The intervening task had an adverse effect on memory performance, but only when the test display appeared immediately after the secondary task. At long delays (of 3.5 seconds), memory performance was on a par with conditions in which there was no intervening task. By varying the similarity between the test and memorized pattern, Experiments 5-6 further showed that performance suffered at early test intervals, unless the test item was dissimilar to the memory item. In conclusion, VWM storage involves multiple types of representation, with unattended memories being more susceptible to interference than others. Moreover, importantly, this fragility has only a temporary status.

23.4021 **No evidence for an object working memory capacity benefit with extended viewing time**
Colin Quirk[1](cquirk@uchicago.edu), Edward Vogel[1]; [1]Department of Psychology, University of Chicago

Multiple studies have shown that visual working memory (VWM) fills within hundreds of milliseconds (Vogel, Woodman, & Luck, 2006) and additional encoding time does not allow for more items to be stored (e.g. Luck & Vogel, 1997). In contrast, recent studies have suggested that there is a VWM capacity benefit for real-world objects at long encoding times (i.e. multiple seconds). For example, Brady, Störmer, & Alvarez (2016) showed that VWM performance for real-world objects is better than for simple colors at long encoding times, supporting the claim that realistic items have more information that can be encoded given sufficient time. Additionally, they measured the contralateral delay activity (a neural marker for the amount of information stored in VWM) and found an increase in CDA amplitude for real-world objects compared to colors for large set sizes at long encoding times, suggesting that this increase in performance is due to an effect of VWM capacity and not long-term memory. In our first experiment, we attempted a direct replication of Brady et al.'s behavioral phenomenon with a larger number of subjects (N=25) and more trials per condition (50 trials per condition). Subjects were asked to remember six real-world objects or colors after a presentation time of 200ms, 1s, or 2s. We failed to replicate their primary behavioral result, instead finding that performance was improved for both colors and real-world objects at longer encoding times. There was no significant difference between VWM performance for colors and real-world objects. Our second experiment was another attempt at a direct replication (N=25) that also included a stronger articulatory suppression manipulation and again we found no performance benefit for real-world objects at long encoding times. These results suggest that there is no additional benefit for real-world objects compared to simple colors under extended viewing conditions.

23.4022 **Encoding strategies in visual working memory**
Hagar Cohen[1](hagarc@mail.tau.ac.il), Halely Balaban[1,2], Roy Luria[1,2]; [1]The School of Psychological Sciences, Tel-Aviv University, [2]The Sagol School of Neuroscience, Tel-Aviv University

The goal of the present study was to examine which type of task, either simple or complex, receives higher priority when encoded into visual working memory. Participants performed the change detection task with arrays of 2 and 3 items that could be either colored squares (the simple task), random polygons (the complex task) or a mixture of both stimuli. By equating the number of items in each comparison while varying complexity level, we were able to measure how the addition of complex object effects the encoding of simple objects and vice-versa. In experiment 1, accuracy for color was not further affected by the addition of polygon relative to adding another color, but polygon performance significantly decreased when appeared next to a color or another polygon, indicating a preference for encoding simple items. In experiment 2 we replaced the random polygons with difficult to distinguish colors, and replicated the results of the previous experiment, suggesting that the results were not due to category preference. In experiment 3, we encouraged participants to encode the polygons by telling them that on trials in which colors and polygons are presented together, the chance of the polygon to be the probed item is much higher than that of color (which was indeed the case). We found an increase in accuracy for polygons (relative to Experiment 1), accompanied with a mild decrease in color performance. Our results suggests that although participant's initial strategy is to encode the items in the simple task, they're able to change it when motivated doing so.

23.4023 **Visual working memory of multiple preferred objects**
Holly Lockhart[1](hl10ze@brocku.ca), Stephen Emrich[1]; [1]Psychology Department, Brock University

A key debate regarding visual working memory (VWM) mechanisms focuses on the differences between discrete- versus continuous-resource models of VWM capacity limits. Recent findings have demonstrated that VWM resources can be allocated disproportionately according to the probability that an item would be probed, consistent with the continuous resource model. However, this finding was based on a single report on each trial, with the assumption that all items in the display would get the predicted quantity of VWM resources. The current study sought to address this methodological limitation, and determine whether multiple items are reported according to attentional prioritization during encoding. Using a two-item report task we tested the flexibility and quality of VWM when two items are cued during the encoding of a super-capacity display of six coloured items. To establish attentional priority, the cued items were probed on 50% of the trials, while in 25% of trials one cued item and one uncued item were reported, and two uncued items were reported on the remaining 25% of trials. Measures of precision, guess rate, and rate of non-target errors were taken from the three-component mixture model. Results show that participants reported the two cued items with approximately equal precision to each other, suggesting that in fact multiple items can be prioritized simultaneously. Uncued items were also half as likely to be correctly reported and three times as likely to be misremembered compared with cued items. The results are in line with the predictions of a flexible resource model in which VWM resources can be allocated across multiple items in accordance with the task demands.

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23.4024 **The precision of visual working memory is set by the number of subsets**
Gaeun Son[1](sohngaeun@gmail.com), Sang Chul Chong[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

The current study investigated whether the precision of visual working memory could be changed by the number of subsets, with the number of items unchanged. Specifically, we always presented five differently oriented bars but varied the number of subsets. We assumed that similarly oriented bars would be organized as one subset while dissimilar bars would be treated as other subsets. Within a subset the orientation difference of all bars was 5°, and across subsets, the smallest orientation difference between two bars was 45°. Thus, within a subset all bars had similar orientations, but across subsets bars had dissimilar orientations. If subsets are used as units of visual working memory rather than individual bars, the precision of represented bars should decrease as the number of subsets increases. In Experiment 1 and 2, five differently oriented bars were presented for 200ms. After 900ms, a bar whose orientation could be adjusted by a mouse was presented in the center of the screen with a circle indicating one specific location of the encoded bars. Participants were asked to recall the orientation of the item indicated by the circle. In Experiment 1, there were two conditions with one subset and two subsets, and in Experiment 2 there were also two conditions with two subsets and three subsets. We compared memory precision between the two conditions in each experiment, with the following steps being taken: (a) the five bars were sorted by their orientations in each subset condition; and (b) the orientation precision of corresponding bars was compared between the subset conditions. We found that the precision of reported orientation decreased as the number of subsets

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increased. These results suggest that items held in visual working memory are organized into subsets depending on orientation similarity and the subsets are represented as units of visual working memory.

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23.4025 Integration of ensemble representations stored in visual working memory

Jifan Zhou[1](jifanzhou@zju.edu.cn), Yijun Zhang[1], Shulin Chen[1], Rende Shui[1], Mowei Shen[1]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University

The "working" function of visual working memory (VWM) has been highlighted by recent studies. Findings demonstrated that the sequentially presented visual elements would be involuntarily integrated into visual objects or figures inside VWM, providing evidence that VWM functions as a buffer serving perceptual processes by storing the intermediate perceptual representations for further processing. In those studies, the number of visual elements was usually controlled within the capacity of VWM; however, the realistic environment we live in is so rich and complex that the visual system has to constantly deal with massive visual information. How is such enormous amount of information actually processed with limited VWM capacity? Notwithstanding researchers know that the visual system can extract statistical properties of crowds of objects to form ensemble representations, it is largely unclear whether and how ensemble representations integrate inside VWM. This issue was investigated in the present study. Participants viewed two temporally separated groups of discs, after a short time, they reported the memorized mean size of either one of the groups or the whole (i.e., all the discs in the two groups) by adjusting a probe disc. The results indicated that participants were able to report accurate mean size of each group and the whole set of discs, respectively. More importantly, the reported mean size of the whole could be predicted by the pooled mean calculated based on the reported means of two individual groups. This result suggested that the temporally separated ensemble representations stored in VWM are able to be integrated into a higher-level ensemble representation, using the perceived statistics of the crowds of objects. Thus, when the amount of objects exceeds the capacity of VWM, the visual system will chose to store the necessary statistics for describing the ensemble and supporting further statistical computation.

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23.4026 Formation and maintenance of mean orientation of sequentially presented objects in visual working memory

Jun Saiki[1](saiki.jun.8e@kyoto-u.ac.jp), Mutsumi Yamaoka[1]; [1]Graduate School of Human and Environmental Studies, Kyoto University

We can perceive ensemble information such as average size and orientation quickly and efficiently. Such efficient statistical perception is observed both with simultaneous and sequential presentation of objects. Mean size information of simultaneously presented objects influences visual working memory (VWM) for each object. However, few studies have addressed the relationship between VWM for ensemble and for single items with sequentially presented objects. This study investigated characteristics of VWM for ensemble formed from sequentially presented items, compared with VWM for ensemble from simultaneously presented items. Participants viewed a sequence of randomly oriented arrow stimuli with 100ms duration for each item and 1000ms inter-item interval, and reported the orientation of their mean or of a particular item. In Experiment 1, participants reported the mean orientation of 4- or 12-item sequence, and multiple regression analysis showed that the beta weight of each item increased as the serial order, indicating a recency effect. To test whether the recency effect simply reflects the property of sequential memory task, Experiment 2 asked participants to report the orientation of all 4 items, and the recency effect disappeared, suggesting that the recency effect is specific to the computation of mean orientation. Next, to examine whether the recency effect occurs only when memory for single items is unnecessary, Experiment 3 asked participants to report either a single item or the mean, depending on the response cue presented after the sequence, and mean orientation trials still showed the recency effect. Furthermore, VWM precisions for a single item and for the mean were comparable, which is inconsistent with studies using simultaneous presentation reporting higher precision with the mean. Taken together, formation and maintenance of mean with sequentially presented items in VWM is distinct from those with simultaneously presented items, and shows a recency effect specific to the mean computation.

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23.4027 An effect of categorical similarity on object-location binding in visual working memory

Yuri Markov[1](ikam.mya@gmail.com), Igor Utochkin[1]; [1]National Research University Higher School of Economics, Moscow, Russia

Research shows that object-location binding errors can occur in VWM indicating a failure to store bound representations rather than mere forgetting (Bays et al., 2009; Pertzov et. al. 2012). Here we investigated how categorical similarity between real-world objects influences the probability of object-location binding errors. Our observers memorized three objects (image set: Konkle et. al. 2010) presented for 3 seconds and located around an invisible circumference. After a 1-second delay they had to (1) locate one of those objects on the circumference according to its original position (localization task), or (2) recognize an old object when paired with a new object (recognition task). On each trial, three encoded objects could be drawn from a same category or different categories, providing two levels of categorical similarity. For the localization task, we used the mixture model (Zhang & Luck, 2008) with swap (Bays et al., 2009) to estimate the probabilities of correct and swapped object-location conjunctions, as well as the precision of localization, and guess rate (locations are forgotten). We found that categorical similarity had no effect on localization precision and guess rate. However, the observers made more swaps when the encoded objects have been drawn from the same category. Importantly, there were no correlations between the probabilities of these binding errors and probabilities of false recognition in the recognition task, which suggests that the binding errors cannot be explained solely by poor memory for objects. Rather, remembering objects and binding them to locations appear to be partially distinct processes. We suggest that categorical similarity impairs an ability to store objects attached to their locations in VWM.

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23.4028 Perceptual organization predicts variability in visual working memory performance across displays and items.

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Growing evidence suggests that visual working memory can store items as perceptual groups rather than as independent units (Brady, Konkle, & Alvarez, 2011). Can perceptual grouping explain particularly high capacity estimates for certain types of stimuli? Based on our previous finding that working memory capacity for orientation is greatly enhanced for line stimuli in comparison to Gabor gratings (Park et al., VSS 2015), here we investigated whether working memory for line orientation can take advantage of Gestalt rules of organization to make more efficient use of its limited capacity. We hypothesized that multiple line orientations can be stored more efficiently if they can be organized into perceptual groups according to the rules of "similarity" and "good continuation". If so, then working memory performance should vary systematically depending on the spatial relations between items in any given visual display. We randomly generated 96 displays, each containing six oriented lines at various locations, and presented the same set of displays to 700+ observers in an online experiment. On each trial, observers were asked to report the orientation of a randomly selected item from memory. Pooling the responses from all observers (110+ trials/item), we observed marked differences in the average error magnitude across displays (25.4˚-39.2˚) and items (19.3˚-84.4˚), which proved highly consistent across observers (a random split-half correlation of .77, $p < .0001$). We characterized the frequency of orientation clustering in the displays, as well as the degree of collinearity among pairs of orientations based on the smoothness of their implied path. By entering these factors into a multiple regression model, we could accurately predict working memory performance for specific displays ($R = 0.62$) and items ($R = 0.40$). Our findings demonstrate that the presence of rich spatial structure in arrays of oriented lines allows for highly efficient storage of information in visual working memory.

23.4029 **Perceptual Grouping Influences Neural Correlates of Spatial Working Memory** Laura Rabbitt[1](lrabbitt@gmu.edu), Craig McDonald[1], Matthew Peterson[1]; [1]Psychology, George Mason University

Spatial working memory is limited in the number of locations that can be maintained over time but can be improved when stimuli are organized into familiar patterns. This study examined the neural correlates of spatial working memory (SWM), specifically if SWM could be measured by the contralateral delay activity (CDA), an event-related potential known to index visual working memory. Additionally, the study investigated whether or not task instruction would alter the amplitude of the CDA in the SWM task. In the current study, participants performed a SWM change detection task where participants were cued to remember the locations of 1 – 4 colored squares on one side of a bilateral array, indicated by a cue prior to the beginning of the trial. At the beginning of the experiment, participants were given one of two instruction types: to remember the individual location of the squares (spatial instructions), or to remember the squares by grouping them into a single unit (constellation instructions). Results of the experiment demonstrated that the CDA indexes the number of items in SWM and increases in amplitude as the number of locations to remember increases. Unlike the spatial instruction condition, the CDA reached an asymptote for two locations in the constellation instruction condition. Additionally, the CDA amplitude was sustained for a longer period of time in the constellation instruction condition than for the individual location instructions. These results indicate that the CDA can measure SWM and how perceptual grouping influence the pattern and duration of neural correlates of SWM.

23.4030 **Successful movement inhibition boosts the inhibition of distractors in visual working memory** Min-Suk Kang[1,2](kangminsuk@skku.edu), Hayoung Song[1,2,3]; [1]Department of Psychology, Sungkyunkwan University, [2]Center for Neuroscience and Imaging Research, IBS, [3]Global Biomedical Engineering, Sungkyunkwan University

The common inhibitory control hypothesis posits that the executive control process is involved in inhibiting thoughts and actions. According to the theory, the inhibition of prepotent response should also facilitate the inhibition of competing representations in memory. To test this hypothesis, in Experiment 1, participants remembered three targets that were presented with either one or five distractors. During the retention interval, they performed a stop-signal task in which they countermanded a simple choice response upon an infrequent stop-signal (25%). We found that the stop-signal trials that were successfully inhibited (canceled trials) resulted in higher memory accuracy than the trials in which the response was erroneously committed (non-canceled trials). This result indicates that the successful response inhibition facilitated the inhibition of distractors and, thus, the working memory performance was enhanced due to reduced distractor intrusion. Alternatively, however, it is possible that the poor memory performance in the non-canceled trials could have occurred because participants adjusted their behaviors after committing errors in the non-canceled trials. We ruled out the post-error processing hypothesis in Experiment 2. Participants remembered three targets that were presented with either one or five distractors like Experiment 1. During the retention interval, they performed a simple shooting task in which they were required to shoot a moving target by pressing a button upon an infrequent shooting-signal (25%). We found that the memory accuracy was comparable whether the shoot hit or missed the target. This result indicates that the post-error processing cannot explain poor memory performance that accompanied non-canceled trials of Experiment 1. Taken together, these results indicate that the common inhibitory mechanism activated by the inhibition of distractors in visual working memory is further boosted by successful response inhibition.

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23.4031 **The time course of retaining the hierarchical representation in visual working memory** Vladislav Khvostov[1](hvo100v@mail.ru), Igor Utochkin[1]; [1]National Research University Higher School of Economics, Russia

It was shown that the features of individual items retrieved from visual working memory (VWM) are systematically biased towards the mean feature of a sample set (Brady & Alvarez, 2011), suggesting hierarchical encoding in VWM. In this work, we investigated how hierarchical representations are stored over time. Observers were shown four white differently oriented triangles for 200 ms and asked to memorize their orientations. After a 1-, 4-, or 7-second delay, they had to report either one individual orientation, or the average orientation of all triangles, rotating a probe circle. We also precued a target (a signal to memorize one particular orientation, all four individual orientations, or the average orientation) or postcued (no signal presented, requiring to remember both the individuals and the average). Using the mixture model (Zhang & Luck, 2008), we estimated the precision and the probability of a tested representation being in VWM, as well as a systematic bias that would indicate hierarchical coding. Participants showed very precise and unbiased memories when only one triangle was precued. However, when they had to remember four orientations their reports were less precise and strongly biased towards the mean, both when the triangles were precued and postcued. However, the bias did not reach the mean, showing that observers had some memory for both the mean and the individual orientations – this is a signature of hierarchical coding. One surprising finding was that the bias towards the mean was slightly stronger after 1 second as compared to 4 or 7 seconds. This suggests that individual representations may be a bit more affected by the mean at early retention stages. However, there were no other substantial changes in the precision, biases, or probability of being in memory with the delay. This suggests that hierarchical representations probably depend more on encoding than retention factors.

Acknowledgement: Program for Basic Research at NRU HSE in 2016

23.4032 **Frequency domain analyses of EEG reveal neural correlates of visual working memory capacity limitations observed during encoding using a full report paradigm.** Kyle Killebrew[1](kylekillabees@gmail.com), Candace Peacock[2], Gennadiy Gurariy[1], Marian Berryhill[1], Gideon Caplovitz[1]; [1]University of Nevada, Reno, Department of Psychology, [2]University of California, Davis, Department of Psychology

Visual working memory (VWM) is capacity limited. In an attempt to better understand the role of encoding-related processes in this capacity limitation, we combined a full report VWM paradigm with an EEG frequency tagging technique to measure neural correlates of encoding related processes. This paradigm allows behavioral and neural responses for all items in a memory array to be measured independently. Specifically, observers performed a full report VWM task in which they were presented with a four-item memory array and asked to recall as many items as possible after a brief delay. The memory arrays contained visual shape stimuli, each flickering at different rates. Each of these was 'tagged' using that particular flicker frequency. While performing the task, neural activity was recorded using high-density electroencephalography (hdEEG) and the steady-state visual evoked potential (SSVEP) was measured during the WM encoding period in response to the frequency tagged stimuli. During retrieval, observers either recalled the location and identity of each item in the order they chose or in an order explicitly demanded by the paradigm. Our results demonstrate that the frequency tag amplitudes for correctly recalled items were larger than for forgotten items for both recall types on electrodes broadly distributed across the scalp. A secondary induced-power analysis found increased power in the theta (5-8Hz), alpha (9-12Hz) and beta (13-31Hz) bands on trails in which 3 or 4 items were correctly recalled compared to 1 or 2 items. However this effect was only observed in the sequential-recall conditions. Building on our previous work using a recognition paradigm, the current results further demonstrate the important role of encoding-related processes in the overall capacity limitation of VWM.

Acknowledgement: NSF 1632738, NSF 1632849

COLOR AND LIGHT: NEURAL MECHANISMS

Saturday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4033 **Luminance modulates the contrast response in human visual cortex** Louis Vinke[1,2](vinke@bu.edu), Sam Ling[2,3,4]; [1]Graduate Program in Neuroscience, Boston University, Boston, Massachusetts, USA, [2]Center for Systems Neuroscience, Boston University, Boston, Massachusetts, USA, [3]Department of Psychological and Brain Sciences, Boston University, Boston, Massachusetts, USA, [4]Donders Institute for Brain, Cognition and Behavior, Radboud University, Nijmegen, The Netherlands

The vast majority of models in vision downplay the importance of overall luminance in the neural coding of visual signals, placing emphasis instead on the coding of features such as relative contrast. Given that the visual system is tasked with encoding surfaces and objects in scenes, which often vary independently in luminance and contrast, it seems plausible that luminance information is indeed encoded and plays an influential role in visuocortical processing. However, the cortical response properties that support luminance encoding remain poorly understood. In this study, we investigate the interaction between contrast response and luminance in human visual cortex, using fMRI. We assessed BOLD responses in early visual cortex (V1-V3) while participants viewed checkerboard stimuli that varied in contrast and luminance. Specifically, we utilized an adaptation paradigm that allowed us to reliably measure contrast responses at multiple spatial scales (voxel-wise and retinotopic), and across a set of luminance levels. To control for changes in pupil diameter with varying luminance levels, stimuli were viewed monocularly through an artificial pupil. We found that the extent to which the overall luminance of a signal modulates responses in visual cortex is contrast dependent, with reliable increases in contrast responses along with increasing luminance levels, but only occurring at low levels of contrast. Furthermore, the modulation strength of luminance on contrast responses did not exhibit any retinotopic bias. These results reveal that the visuocortical neural code does indeed retain and utilize information about the luminance of a visual signal, but appears to preferentially modulate the response only at low-to-zero contrast levels. This finding suggests that luminance likely plays a dominant role in visual tasks such as our perceptual encoding and segregation of surfaces.

23.4034 Receptive Field Structures of Color-responsive Neurons in Macaque Monkey V1

Wei-Ming Huang[1](waggamsn@gmail.com), Hsiang-Yu Wu[1], Yu-Cheng Pei[2], Chun-I Yeh[1,3,4]; [1]Department of Psychology, National Taiwan University, Taiwan., [2]Department of Physical Medicine and Rehabilitation, Chang Gung Memorial Hospital, Taiwan., [3]Neurobiology and Cognitive Science Center, National Taiwan University, Taiwan., [4]Institute of Brian and Mind Sciences, National Taiwan University, Taiwan.

Visual receptive fields have been studied as a way to understand the properties of color- and luminance-responsive neurons in the primary visual cortex (V1). In macaque monkey V1, many neurons responding to color are highly selective for orientation and spatial frequency (Johnson et al., 2001; Friedman et al., 2003). One would predict that the receptive field structures of color-responsive neurons should consist of multiple elongated sub-regions (like simple cells). However, previous studies had shown mixed results: some found simple-cell-like receptive fields by using dense noise (Horwitz et al., 2007; Johnson et al., 2008), whereas others found receptive fields that were blub-like and less elongated when using sparse noise (Conway and Livingstone, 2006). Here we measured receptive fields of V1 color-responsive neurons with three different stimulus ensembles: Hartley gratings, binary white noise, and binary sparse noise. All three stimulus ensembles consisted of equiluminance colors of red and green representing different cone weights. Receptive fields were estimated by reverse correlation and fitted with the 2-D Gabor function. We studied 54 V1 units and found that Hartley maps tended to have higher aspect ratios ($p=0.03$) and larger numbers of subregions ($p=0.02$) than white-noise maps (Friedman's test). There was a negative correlation between the aspect ratio of the map and the circular variance measured with drifting gratings (Hartley gratings: $r=-0.28$, $p=0.04$; white noise: $r=-0.30$, $p=0.04$; Spearman's rank correlation). Similar to previous findings, the distribution of circular variances for color-responsive neurons was comparable with that for luminance-responsive neurons (Leventhal et al., 1995; Ringach et al., 2002). In summary, the receptive field of color-responsive neurons may change accordingly with different stimulus ensembles. For neurons that are well tuned for orientation, the tuning properties can be predicted by their receptive field structures.

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23.4035 Quantifying the relation between pupil size and electrophysiological engagement of visual cortex

Nina Thigpen[1](nthigpen@ufl.edu), Andreas Keil[1]; [1]University of Florida

Little is known about how physical properties of the eye influence how light information is received in early visual cortex. In humans, mass activity in the primary visual cortex can by quantified by measuring the steady-state visually evoked potential (ssVEP). Given that both the ssVEP and pupil size are often modulated by the same manipulations, such as stimulus brightness and physiological arousal, the question arises whether pupil size is directly related to the amount of primary visual cortical engagement to a given stimulus. To test this hypothesis, we systematically manipulated pupil size by manipulating the brightness of five sinusoidal gratings, shown one at a time to participants for 3 seconds, 40 times each. Each stimulus flickered at either 6, 10, or 15 Hz, to elicit ssVEPs, used as a measure of visual cortical engagement. We observed a strong negative linear relation between pupil size and ssVEP amplitude, across participants and driving frequencies. Surprisingly, we observed a quadratic relationship between pupil size and the amplitude of the second harmonic of the driving frequency. These results suggest that there is a systematic relation between pupil size and mass activity in primary visual cortex that is not explained by light energy entering the retina. The data may play an important role in the understanding of the bi-directional relationships between the autonomic nervous system and primary visual cortex.

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23.4036 Tracing the representation of colored objects in the primate brain

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Even though color vision is commonly defined as the ability of an organism to distinguish objects based on the wavelengths of light they reflect, color research has mainly focused on the representation of colors independent of the problem of distinguishing objects. Thus the mechanism by which color contributes to object recognition remains unclear, as little is known about how color and object information are co-represented in the part of the brain responsible for object recognition: in primates, inferotemporal (IT) cortex. The recent discovery of "color patches" in macaque IT cortex makes this problem experimentally tractable. Here we recorded neurons in three color patches, middle color patch CLC, and two anterior color patches ALC and AMC, while presenting images of objects systematically varied in hue. We found that all three patches contain high concentrations of hue-selective cells, and carry significant information about both hue and object identity. We found two clear transformations across the three patches. The first transformation, from CLC to ALC, reduces information about object identity. The second transformation, from ALC to AMC, mainly affects representation of hue: color space is represented in a dramatically distorted way in AMC, with over-representation of yellow and red, the natural colors of mammal faces and bodies; furthermore, AMC develops an expanded representation of primate faces, displaying hue-invariant representation of monkey identity. Our findings suggest that IT cortex uses three distinct computational strategies to represent colored objects: multiplexing hue and object shape across all objects (CLC), extracting hue largely invariant to shape (ALC and AMC), and multiplexing hue and object shape specifically for ecologically important objects (AMC). Overall, our study reveals the neural architecture for representing colored objects in IT cortex, and sheds light on the general organizational principles of IT cortex.

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23.4037 Electrophysiological correlates of perceptual blue-yellow asymmetries with #thedress

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Asymmetries in blue-yellow color perception, in which blues appear less saturated than yellows of equivalent chromatic contrast, have been shown to affect a variety of color percepts including the appearance of #thedress (Winkler et al, 2015). This asymmetry may reflect greater ambiguity about the source of bluish tints compared to other hues, e.g., whether the blue is due to the lighting or the surface. When the blue is inverted to yellow, this ambiguity may be removed, and agreement about the inverted dress color is much higher. We tested for neural correlates of this perceptual asymmetry using a paradigm for measuring asymmetries in visual discrimination with high-density electroencephalography (EEG) and frequency tagging (Retter & Rossion, 2016). Throughout four 50-sec sequences, the original

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dress image was presented in alternation with the color-inverted image at a rate of six images per second (6 Hz), with measurements collected for 14 observers. Given that the color-inverted image is consistently perceived to have yellow stripes, we hypothesized that an asymmetry between the two images would be present in the EEG recording at the alternation rate (3 Hz). Settings were also made for a second pair of dress images formed by rotating the original colors by +/-90 deg to create reddish-greenish versions, for which a less-pronounced perceptual asymmetry predicts a weaker 3 Hz response. These hypotheses were supported, with larger blue-yellow than red-green responses at 3 Hz and its specific harmonics (e.g., 9 Hz) in the frequency-domain of the EEG over occipital channels. In contrast, the response at the image-presentation rate of 6 Hz and its harmonics did not differ across these two conditions. Our results suggest that the blue-yellow asymmetry, a potentially higher-level aspect of color appearance unrelated to chromatic sensitivity, is nevertheless evident in electrophysiological recordings of the cortical responses to color.

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23.4038 **Differential effects of four types of TMS on signal processing** Greta Vilidaite[1](gv529@york.ac.uk), Daniel Baker[1]; [1]Department of Psychology, University of York

Transcranial magnetic stimulation (TMS) is often used to link behaviour to anatomy by targeting a brain area during an associated task. Decreases in performance on that task are often explained as a suppression of stimulus-driven signals, but could also be explained by increases in neural noise. This study used a 2IFC double-pass contrast discrimination paradigm (Burgess & Colborne, 1988, J Opt Soc Am A, 5:617-627) to distinguish between these two possibilities in four types of TMS: online single-pulse (spTMS), online three-pulse repetitive (rTMS), offline continuous (cTBS) and intermittent theta burst stimulation (iTBS). Using standard stimulation protocols with a Magstim Super Rapid2, online TMS was applied to early visual cortex 50ms after onset of each stimulus in each interval, and offline TBS was applied before the start of the task. On each trial (200 total) two grating stimuli of random contrast were presented peripherally (position determined by phosphene localization). Half of the trials contained a 4% contrast increment in one of the intervals. The exact same trial sequence was then repeated with randomized interval order (second pass). A decrease in accuracy in the 4% target condition would indicate signal suppression whereas a reduction in consistency of responses between the two passes would indicate an increase in neural noise. Mean accuracy and consistency scores were bootstrapped within participants. It was found that spTMS reduced accuracy whereas rTMS decreased consistency. This implies that spTMS decreases signal strength whilst rTMS increases neural noise without affecting the stimulus-driven signal. Offline stimulation (cTBS, iTBS) did not affect accuracy or consistency. This is the first study to compare several types of TMS using a single paradigm that can dissociate noise from suppression. These findings can explain inconsistencies in results between previous studies using different TMS protocols and so comparisons across protocols should be made with caution.

Color and Light: Constancy

Saturday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4039 **Memory Bias for Illumination Colour** Stacey Aston[1](stacey.aston1@ncl.ac.uk), Maria Olkkonen[2,3], Anya Hurlbert[1]; [1]Institute of Neuroscience, Newcastle University, UK, [2]Psychology, Durham University, UK, [3]Institute of Behavioural Sciences, University of Helsinki, Finland

Perceptual estimates of surface colour are biased in memory toward the mean of recently viewed colours (Olkkonen et al. 2014). Discrimination of global illumination colour is also biased, with discrimination thresholds enlarged for illumination changes opponent to the adaptation illumination; yet overall discrimination is poorest for bluish illumination changes (Aston et al. 2015). Does memory for illumination colour show the same central tendency as surface colour, and are biases for memory and discrimination linked? Participants (n=7) viewed an enclosed grey wall illuminated by tuneable multi-channel LED lamps. Following an initial 2-min adaptation period under D65 illumination, participants viewed on each trial: reference light (500 ms), top-up adaptation light (2000 ms), and test light (500 ms); then (under D65) responded by button press whether the test was “bluer or yellower” than the reference. Each of three trial blocks contained 5 reference illuminations covering a greenish-blue chromaticity range in equal perceptual steps; the three reference sets overlapped but had different means. All illuminations were the smoothest-possible metamers for the requested chromaticity. The point of subjective equality (PSE) for each reference in each block was determined by averaging the final reversals of two interleaved one-up, one-down staircases, one approaching the reference from yellower hues, the other bluer. PSEs were systematically biased towards the mean of each block (the same illumination was remembered as more yellow when all references were biased towards yellow, compared to when biased towards blue). The set of illuminations perceptually equal to each reference chromaticity, defined as all hues between the convergence points of the two staircases, are skewed towards bluer hues. While illumination colour memory shows the same bias towards recent stimuli as surface colour memory, there is an additional bias towards blue which may result from poorer discrimination or prior expectations for illumination colour.

23.4040 **The optics, perception and design of light diffuseness in real scenes** Sylvia Pont[1](s.c.pont@tudelft.nl), Ling Xia[2], Tatiana Kartashova[1]; [1]Perceptual Intelligence lab, Industrial Design Engineering, Delft University of technology, [2]Changzhou key Laboratory of Robotics and Intelligent Technology, College of Internet of Things Engineering, Hohai University, China

Human observers can perceive intensity and direction differences of the illumination on objects and in scenes. They also have a sense for the light diffuseness. Reviewing studies into light diffuseness perception and practical lighting guidelines we encountered the problem that there is no agreement on how to describe and measure the light diffuseness, complicating comparisons. We found a large variety of metrics relating to visual effects of light diffuseness, including contrast, shape expressing, material expressing, and atmosphere effects. Moreover, many metrics appeared to be application-, context- or even object-specific. We compared four approaches and propose a normalized metric for light diffuseness, ranging from 0, meaning fully collimated light (a beam with zero spread), to 1, meaning fully diffuse or Ganzfeld illumination. We developed a measurement method for real scenes using cubic illuminance metering. We tested metric and method using simulations, measurements on Debevec luminance maps using a cubic and tetrahedron shaped meter, and measurements in real scenes using the cubic meter. We also tested the influence of scene properties (lighting, geometry and furnishing) and variations within scenes. We compared optical against psychophysical data from our own and other studies, and against practical lighting guidelines. We found that the cubic meter method and metric give robust measurements of light diffuseness. Measurements in real scenes fell in a wide range of 0.1 – 0.9. We found extremely strong effects of furnishing and geometry. Such material-lighting interactions in scenes / architectural spaces are not well-understood and form a challenge in practical lighting design. Most practical guidelines note a broadband range centered slightly above medium diffuseness or hemispherical diffuse light (overcast sky). The psychophysical data contract to narrow bands, depending on the type of scene (varying per experiment), suggesting a template representation of light diffuseness that depends on the overall appearance of a scene.

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23.4041 **Contrast adaptation and illuminant spectra** Ivana Ilic[1](ivanailic@nevada.unr.edu), Lorne Whitehead[2], Michael Webster[1]; [1]Department of Psychology, College of Liberal Arts, University of Nevada, Reno, [2]Department of Physics and Astronomy, University of British Columbia

Artificial illuminants vary widely not only in their mean chromaticity but also in the range or gamut of colors they produce. For example, new high-gamut LED illuminants can expand the saturation of reds and greens by roughly 30%. We explored how the visual system might adapt to changes in the color distributions induced by different illuminants. A set of simulated surfaces (Munsell spectra) was constructed to form a uniform circle of chromaticities in cone-opponent space, when illuminated by a Plankian radiator with a color temperature of 2724 or 4000 K. Corresponding sets were then calculated for the same surfaces under a 3-primary LED spectrum with the same mean chromaticity. Observers simultaneously adapted for 3 minutes to a random sequence of the same surfaces under each pair of Plankian vs. LED sources, shown in two 4-deg fields above and below fixation. A

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new color was sampled from the distributions every 200 ms. Test stimuli were then shown for 500 ms in the two fields and interleaved with 4 sec of re-adaptation. The tests included 16 chromaticities uniformly sampling different chromatic angles relative to the illuminant mean. The test pair were yoked so that increasing the test contrast in the top field reduced it in the bottom field or vice versa, and observers adjusted them to match their appearance. These matches required significantly higher contrast along the reddish-greenish axis for the LED adaptation, consistent with a sensitivity loss induced by selective adaptation to the higher red-green contrast created by the LED spectra. Our results suggest that commonly available light sources may significantly alter the states of contrast adaptation in the visual system, and that this contrast adaptation is important for understanding the perceptual consequences of both short and long-term exposure to different illuminants. Funding: EY-10834

Acknowledgement: EY-10834

23.4042 **Universal information limit on real-world color constancy** David Foster[1](d.h.foster@manchester.ac.uk), Iván Marín-Franch[2]; [1]School of Electrical and Electronic Engineering, University of Manchester, Manchester, UK, [2]Faculty of Optics and Optometry, University of Murcia, Murcia, Spain

The light reflected from scenes under the sun and sky changes over the course of the day, yet the reflecting properties of individual surfaces appear unchanged. The phenomenon of color constancy is often attributed to operations applied to cone photoreceptor signals. These operations include cone-specific adaptation such as von Kries scaling, typically by average scene color or the brightest color; transformations of combinations of cone signals; and transformations of the whole color gamut, e.g., for optimum color discrimination. But are any of these or similar operations sufficient for constancy in the real world, where both spectral and geometric changes in illumination occur, including changes in shadows and mutual illumination? To address this question, cone signals were calculated from time-lapse hyperspectral radiance images of five different outdoor scenes containing mixtures of herbaceous vegetation, woodland, barren land, rock, and rural and urban buildings. Shannon's mutual information between cone signals was estimated across successive time intervals. Combined with the data processing inequality from information theory ("functions of data cannot increase information"), these estimates set an upper limit on the performance of any color constancy operation using cone signals alone. For all five scenes, the information limit declined markedly with increasing time interval, though not always monotonically. This pattern was little altered by changing the way that cone signals were initially sampled before information was estimated, e.g., taking spatial ratios of signals, omitting signals from dark regions of scenes, and using local statistical features (local mean, maximum, and standard deviation of cone signals). Moreover, dividing scenes into a mosaic of smaller patches for independent processing did not improve performance. It seems that operations on color signals alone are insufficient to uniquely identify the reflecting properties of individual surfaces. Reliable color constancy in the real world depends on more than just color.

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23.4043 **Appearance of surface property influenced by the diffuseness of lighting** Yoko Mizokami[1](mizokami@faculty.chiba-u.jp), Yuki Kiyasu[1], Hirohisa Yaguchi[1]; [1]Graduate School of Advanced Integration Science, Chiba University

Lighting condition could largely influence the appearance of object surface property. It is known that the components of specular and diffuse reflection change depending on the diffuseness of lighting. The diffuseness of lighting could influence the appearance of various surface properties, and it would be important to investigate them systematically. We previously examined how the impression of surface appearance of test samples with different roughness and shape changed under diffused light and direct light, and our results suggested that glossiness and smoothness were main factors influenced by the lighting conditions (ECVP2016). Here, we further examine how the surface appearance of test samples with different roughness and shape changed by diffused light and direct light using real samples in real miniature rooms. We prepared plane test samples with three different levels of surface roughness and spheres with matt and gloss surfaces. A sample was placed in the center of a miniature room with either directed light or diffused light. We used a magnitude estimation method for evaluations. Observers evaluated its appearance in terms of glossiness, naturalness, translucency, sharpness, saturation, brightness, roughness, heaviness, hardness, and preference. They rated the appearance of test samples under diffused light for each item in comparison with that under the direct light, which was served as a reference. The results showed the difference of appearance in all items under directed and diffused lights. Those shifts were generally larger in glossiness, sharpness, brightness, and roughness, implying that those factors are especially influenced by the diffuseness of lighting. Samples tended to appear less glossy and smother under diffused light than direct light, and their difference was larger for a sample with rough surface. These trends were consistent with our previous finding.

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23.4044 **Unraveling simultaneous transparency and illumination changes** Robert Ennis[1](Robert.Ennis@psychol.uni-giessen.de), Katja Doerschner[1]; [1]Justus-Liebig University, Giessen, Germany

Retinally incident light is an ambiguous product of spectral distributions of light in the environment and their interactions with reflecting, absorbing, and transmitting materials. An ideal color constant observer would unravel these confounded sources of information and account for changes in each factor. We have previously shown (VSS, 2016) that when observers view the whole scene, they can disentangle simultaneous changes in the color of the illumination and the surfaces of opaque objects, although standard global scene statistics in the color constancy literature did not fully account for their behavior. Here, we have extended this investigation to simultaneous color changes in the color of the illuminant and of glass-like blobby objects (similar to Glavens (Phillips, et. al., 2016)). To simulate changes in the color of the illuminant and of transparent objects, we made a simple physically-based GPU-accelerated rendering system. Color changes were constrained to "red-green" and "blue-yellow" axes. At the beginning of the experiment, observers (n=6) first saw examples of the most extreme illuminant/transparency changes for our images. They were asked to use these references as a mental scale for illumination/transparency change (0% to 100% change). Next, they used their scale to judge the magnitude of illuminant/transparency change between pairs of images. Observers viewed sequential, random pairs of images (2s per image) with a view of the whole scene or of only the object itself (produced by masking the scene). Observers were capable of extracting simultaneous illumination/transparency changes when provided with a view of the whole scene, but were worse when viewing only the object. Global scene statistics did not fully account for their behavior in either condition. We take this as suggesting that observers make use of local changes in shadows, highlights, and caustics across different objects to determine the properties of the illuminant and the objects it illuminates.

23.4045 **#thedress: A Tool for Understanding How Color Vision Works** Rosa Lafer-Sousa[1](rlaferso@mit.edu), Bevil Conway[2]; [1]Department of Brain and Cognitive Sciences, MIT, [2]Laboratory of Sensorimotor Research, National Eye Institute, NIH

The "dress" photograph provides an opportunity to investigate how the brain resolves stimulus ambiguity to achieve color. We analyzed responses from a large number of naïve and non-naïve subjects, collected in lab and online. First, contrary to initial scientific reports suggesting a wide range of dress percepts, using K-means clustering to analyze color-matching responses we find the dress was viewed categorically (white/gold and blue/black) among observers who had seen the photograph before and naïve subjects (color-matching responses predicted subjects' categorical labels, binomial regression). As well, 48% of observers self-reported experiences of perceptual switching (W/G switched less often). These results show that #thedress is analogous to bi-stable shape images. Second, we quantitatively compared color-matching responses obtained online and in laboratory, and performed a power analysis to determine the number of subjects required to obtain results representative of the general population. We conclude that initial scientific studies were underpowered. Third, observers descriptions of the lighting conditions were predictive of the colors seen (binomial regression); W/G observers typically inferred a cool illuminant, whereas B/K observers inferred a warm illuminant. Fourth, subjective reports of where in the image subjects looked revealed systematic differences between B/K and W/G observers. Fifth, we show

here that when the dress is cropped from the rest of the photograph, and digitally placed on a female model, a color tint applied to the model's skin that reflects the illuminant was sufficient for observers to disambiguate the illuminant color and achieve a predictable perception of the dress' colors. Finally, presenting versions of the photograph with unambiguous lighting cues influenced how subjects reported the dress' colors in subsequent viewings of the original photograph. Together the results document a powerful example of a bi-stable color image, and illustrate how multiple perceptual and cognitive cues are used by the brain to resolve color.

23.4046 **Luminance-contrast reversal disambiguates illumination interpretation in #TheDress** Shigeki Nakauchi[1](nakauchi@tut.jp), Kai Shiromi[1], Hiroshi Higashi[1], Mohammad Shehata[1,2], Shinsuke Shimojo[2]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology, [2]Biology and Biological Engineering, California Institute of Technology

Background: One of the potential hypothesis for explaining the individual differences in perceiving #TheDress is ambiguity in illumination interpretation. Asymmetry between luminance and blue-yellow in variations of natural sunlight is suspected to play an important role. Here, to test the hypothesis, color matching experiments were conducted for variants of #TheDress. Methods: As for the visual stimuli, we manipulated the hue and/or luminance contrast of the original #TheDress: original (OR), hue reversed (HR), luminance contrast reversed (LR), hue and luminance contrast reversed (HLR). Observers were asked to view one of these images displayed on a calibrated monitor and to match the dress/lace colors in CIELUV uniform color space by selecting the closest color among 25 uniform rectangular color patches equally spaced in L*, u* and v* coordinates by button press. Observers were pre-categorized into blue-black (BK) and white-gold (WG) groups by their color naming responses to the original. Results: Matches between BK and WG differ in L* (lightness) and v* (blue-yellow direction) for the OR which duplicated the previous observations. However, L* matches for the bright lace part in the HR image still differ among groups although individual differences in color naming vanished. For both the LR and HLR, however, we found no differences in matches between groups although the HLR image had the same luminance-color structure (bright blue and dark yellow) as the original. Discussions: Results imply that luminance-contrast polarity is the one of the key factors affecting the individual differences in #TheDress. This is because reversing the luminance-contrast may disambiguate indirect/direct illumination interpretations. Furthermore, specular highlights do not work as a local cue for the illuminant color in the luminance-contrast reversed images.

23.4047 **Color quality assessments of 3D facial prostheses in varying illuminations** Kinjiro Amano[1](k.amano@manchester.ac.uk), Ali Sohaib[2], Kaida Xiao[3], Julian Yates[1], Charles Whitford[4], Sophie Wuerger[2]; [1]School of Medical Sciences, University of Manchester, UK, [2]Institute of Psychology Health and Society, University of Liverpool, UK, [3]School of Design, University of Leeds, UK, [4]School of Engineering, University of Liverpool, UK

Skin color provides essential information about an individual's health condition and emotion. Additive manufacturing of human skin has been developed markedly in recent years along with increasing demands for clinical and medical applications. It is therefore critical to achieve precise color reproduction of facial skin and constant color appearance under different illuminations particularly for the application to maxillofacial prostheses. In this study, the color quality of 3D facial prostheses under various illuminations was assessed by measuring human perceptual error, quantified by the color difference metric CIEDE2000, and an index for color constancy. The index was calculated in the same manner as a standard color-constancy index. Thus, in a color space, where the chromaticity coordinates of real skin and artificial skin were located, let a be the distance between real skin and artificial skin colors under a test illuminant and let b be the distance between the real skin color under test and reference illuminants, then the index is 1 – a/b. Perfect constancy corresponds to unity and the greater the error, the lower the index. 3D facial prostheses of three human subjects, one Caucasian and two Chinese, were generated by an additive manufacturing with an elaborated color management from 3D color digital imaging to 3D printing. Colors of the 3D prostheses and subjects' real skin were compared with a spectrophotometer. Mean color difference CIEDE2000 over subjects was approximately 7.2 (a Caucasian 5.7, two Chinese 7.9), slightly larger than the conventional values of acceptable perceptual error (4.0). Despite these differences, color constancy indices between selected CIE standard illuminants (D65, A, F2, F11) ranged over 0.57–0.84, close to values from traditional color-constancy experiments with human observers. The color quality of facial prostheses in modern additive skin manufacturing may be as good perceptually as that of real human skin, even under different scene illuminations.

Acknowledgement: EPSRC, UK (EP/L001012/1 and EP/K040057)

23.4048 **When the brightest is not the best: Illuminant estimation based on highlight geometry** Takuma Morimoto[1](takuma.morimoto@new.ox.ac.uk), Robert Lee[2], Hannah Smithson[1]; [1]University of Oxford, Department of Experimental Psychology, [2]University of Lincoln, School of Psychology

To achieve color constancy, the visual system must estimate the illuminant. An influential proposal for illuminant estimation is to assume that the brightest element in a scene is either a white surface or a specular highlight and therefore provides the illuminant color. We tested an alternative hypothesis: Observers use the geometry of the surface and the illumination to select highlight regions, even when they are not the brightest elements in the scene. In computer-rendered scenes we manipulated the reliability of the "brightest element" and the "highlight geometry" cues to the illuminant, and tested the effect on performance in an operational color constancy task. To eliminate other cues to the illuminant, scenes contained only a single spherical surface illuminated by multiple point sources of light, each with the same spectral content. The surface reflectance took a single spectral distribution but was modified by surface texture that attenuated the reflectance by a variable scale factor. The surface had one of three levels of specularity: zero (matte), low and mid. In the experiment, observers saw a one-second animation and their task was to indicate if the color change was due to an illuminant change or a material change. Discrimination performance was close to chance for matte surfaces, as predicted. However, as specularity increased, performance significantly improved. Importantly, it was shown that performance exceeded the prediction given by an ideal observer using the brightest element to perform the discrimination. Moreover, separate analyses for trials in which the specular region fell on a dark part of the texture showed an additional performance enhancement, even though the brightest element heuristic would predict a performance decrease. These results suggest that human observers do not simply rely on the brightest element in constancy tasks, but rather utilize the geometry of specular regions to separate surface and illuminant properties.

Acknowledgement: Wellcome Trust (094595/Z/10/Z)

BINOCULAR VISION: CONTINUOUS FLASH SUPPRESSION AND AWARENESS

Saturday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4049 **Why are dynamic Mondrian patterns unusually effective in inducing interocular suppression?** Shui'Er Han[1](han.shuier@gmail.com), Garry Kong[1,2], Randolph Blake[3], David Alais[1]; [1]School of Psychology, University of Sydney, [2]Science Division, New York University Abu Dhabi , [3]Department of Psychology, Vanderbilt University, Nashville, TN 37240

In so-called continuous flash suppression (CFS), a dynamic sequence of Mondrian images presented to one eye effectively suppresses a static target in the other eye for many seconds at a time. This strong and enduring interocular suppression is generally attributed to the rapid Mondrian pattern changes, which resemble a series of backward and forward masks. However, using spatiotemporal filtering techniques, recent studies demonstrate similarities with binocular rivalry, with CFS producing strong suppression when stimuli favouring parvocellular streams (slow temporal modulations) are used and when target/masker attributes are matched. To evaluate this discrepancy, we manipulated the pattern and temporal structure of a 10 Hz Mondrian and measured the respective effects on suppression durations. The Mondrian pattern is an ideal masker because it contains an abundance of edge and contour information and these features influence both visual temporal masking and rivalry suppression. Compared to phase scrambled Mondrians, our findings reveal significantly longer suppression durations for intact Mondrian patterns. This suppressive advantage applied to both location and identity judgments, and was predominantly driven by pattern edges. Updating the Mondrian smoothly and continuously resulted in lower suppression durations than the standard, discrete presentation schedule, demonstrating the significant contribution of visual temporal masking in CFS. The differences in suppression durations with an intact, discretely updated Mondrian masker also varied with temporal frequency content, suggesting that there might be a dual component mechanism in CFS involving temporal masking and interocular suppression.

23.4050 **Mechanisms of suppression: How the classic Mondrian beats noise in CFS masking** Weina Zhu[1,2](zhuweina_xm@sina.com), Jan Drewes[2], David Melcher[2]; [1]School of Information Science, Yunnan University, 650091 Kunming, China, [2]Center for Mind/Brain Sciences (CIMeC), University of Trento, 38068 Rovereto, Italy

In a typical Continuous Flash Suppression (CFS) paradigm (Tsuchiya & Koch, 2005), a series of different "Mondrian" patterns is repeatedly flashed to one eye, suppressing awareness of the image presented to the other eye. In our previous study (Zhu, Drewes, & Melcher, 2016), we found that the spatial density of the Mondrian patterns affected the effectiveness of CFS. To better understand this finding, we varied the shape and edge information in the mask. Typical Mondrian-style masks are made from individual rectangular patches, resulting in sharp horizontal and vertical edges between neighboring luminance levels. To investigate the role of these edges, we compared grayscale Mondrian masks with various noise patterns as well as phase-scrambled Mondrian equivalents and "Klee" masks (a type of pink noise mask with edges). We employed a breakthrough CFS paradigm with photographic face/house stimuli and a range of temporal masking frequencies (3-16Hz). The noise patterns were white noise with spatial frequency filtering applied, resulting in noise spectra ranging from 1/f0.5 to 1/f10. Subjects (N=16) were instructed to press the button as soon as they saw any part of the stimulus. Results show that the most effective mask was the classic Mondrian. Among the noise masks, pink noise (1/f1) lead to longer suppression while the least effective masking was achieved by 1/f10 noise. Interestingly, the masking effectiveness of the phase-scrambled Mondrian masks as well as the "Klee" masks was not significantly different from pink noise. Adding edges to noise masks therefore did not significantly improve masking effectiveness. Phase scrambling the Mondrian patterns did significantly reduce their effectiveness. The remaining advantage Mondrian masks have over random noise patterns may result from the higher effective contrast range or presence of surface shapes afforded to the Mondrians by the patchwork design.

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23.4051 **Different suppressing stimuli produce different suppression in the continuous flash suppression paradigm** Motomi Shimizu[1](shimizumtm@chiba-u.jp), Eiji Kimura[2]; [1]Graduate School of Advanced Integration Science, Chiba University, Japan, [2]Department of Psychology, Faculty of Letters, Chiba University, Japan

Purpose: Stimulating one eye with a high-contrast dynamic stimulus can render a salient stimulus in the other eye invisible (continuous flash suppression; CFS). We have previously demonstrated, using a flickering achromatic Gabor as the suppressing stimulus, that successive exchanges of the eye-of-presentation led to breaking suppression (Shimizu & Kimura, VSS2016). This finding suggested that CFS is mainly mediated by eye- rather than stimulus-based suppression. This study aimed to extend the previous finding and investigated whether different suppressing stimuli such as Mondrian patterns would produce similar or different suppression. Method: The suppressing stimulus was a series of different Mondrian patterns presented at a rate of 5 Hz. The patterns were either achromatic or chromatic. The target was an achromatic Gabor patch (2.5 cpd, sigma = 0.22°, 40% contrast). The eye of presentation was manipulated in three conditions. In the dichoptic condition the suppressing stimulus was presented to the observer's dominant eye and the target was to the other. In the eye-swap condition the two stimuli were dichoptically presented but repeatedly exchanged between the eyes at every 1 second. In the monocular condition they were presented in the same eye. We asked observers to detect the target as soon as possible and measured detection time. Results & Discussion: In the dichoptic condition, Mondrian patterns, whether achromatic or chromatic, produced longer detection time (i.e., stronger suppression) than the Gabor patch used previously. Moreover, in contrast to the results with the Gabor, Mondrian patterns resulted in significantly longer detection time (3.7 sec) in the eye-swap condition than in the monocular condition (1.9 sec), although the suppression was much reduced relative to that in the dichoptic condition (8.7 sec). The significant, although reduced, suppression in the eye-swap condition cannot be easily accounted for by eye-based suppression, and implicates a partial contribution of eye-independent, possibly stimulus-based, suppression.

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23.4052 **Analyzing the time course of processing invisible stimuli: Applying event history analysis to breaking continuous flash suppression data.** Pieter Moors[1](pieter.moors@kuleuven.be), Johan Wagemans[1]; [1]Laboratory of Experimental Psychology, Department of Brain and Cognition, University of Leuven (KU Leuven)

Breaking continuous flash suppression (b-CFS) is an interocular suppression paradigm in which the time to detect an initially suppressed stimulus is measured for different classes of stimuli. For example, in one classic study Jiang et al. (2007) reported shorter suppression times for upright compared to inverted faces. Because such a difference was not observed in a perceptually matched condition which did not involve interocular suppression, Jiang et al. argued to have provided evidence for unconscious processing of face stimuli. Although the suitability of b-CFS as a paradigm for unraveling the scope and limits of unconscious processing has already been firmly criticized, it is still argued that the paradigm is useful because increased suppression durations allow for more elaborate processing of the perceptually suppressed stimulus and hence certain effects can be detected more easily. In this study, we explicitly tested this claim by applying event history analysis to a set of b-CFS studies that were collected during the last years. Event history analysis refers to a set of statistical methods for studying the occurrence and timing of events while explicitly taking the passage of time into account. For an experiment comparable to Jiang et al. (2007), our analyses show that, over the course of a trial, the hazard (i.e., probability of response occurrence at time t, given that no response has occurred yet) associated with upright faces was higher compared to inverted faces, supporting faster breakthrough of upright faces. However, this face orientation effect did not interact with time, indicating no differential evolution over time for the hazard functions associated with upright and inverted faces. We discuss these results in the context of current discussions on the usefulness of b-CFS paradigms to allow for more elaborate processing of the perceptually suppressed stimulus.

Acknowledgement: METH/02/14

23.4053 **Perceptual learning does not affect access to awareness** Chris Paffen[1](c.l.e.paffen@uu.nl), Surya Gayet[1], Micha Heilbron[1], Stefan Van der Stigchel[1]; [1]Experimental Psychology & Helmholtz Institute, Utrecht University

Visual information that is relevant for an observer can be prioritized for access to awareness (Gayet et al., 2014). Here we investigate whether information that became relevant due to extensive training is prioritized for awareness. Participants performed in 3-day speed discrimination training involving dots moving in two directions, of which one was task-relevant (the attended direction) and the other was task-irrelevant (the ignored direction). Before and after training, we measured detection times for reporting the location of moving dots that were initially suppressed from awareness by continuous flash suppression (a method which is often used to assess prioritization for access to awareness called breaking continuous flash suppression; b-CFS). We hypothesized that b-CFS durations for the attended direction would selectively decrease after training. We also measured motion coherence thresholds for the attended, ignored and a neutral motion direction before and after training. Results show that perceptual learning took place: during training, speed discrimination of the attended motion direction became increasingly better. Also, coherence thresholds for the attended motion direction decreased after training, while thresholds for ignored and neutral motion directions were unaffected. B-CFS durations decreased after training for all three motion directions, revealing no selective decrease for the previously attended motion. A follow-up experiment showed that b-CFS durations also decreased after three days without training, revealing that perceptual learning did not cause the general decrease in b-CFS durations. We conclude that information that has become relevant due to extensive training is not prioritized for access to awareness. Our experiments do show, however, that b-CFS durations decrease for stimuli that are shown in succession, even when measurements are separated by several days. The latter has important consequences for studies applying b-CFS to assess access to awareness. Gayet, S., Van der Stigchel, S., & Paffen, C. L. E. (2014). Front Psychol, 5, 460.

23.4054 The Functional Order of Binocular Rivalry and Blind Spot Filling-in

Stella Qian[1](qianche5@msu.edu), Jan Brascamp[1,2], Taosheng Liu[1,2]; [1]Department of Psychology, Michigan State University, [2]Neuroscience Program, Michigan State University

Binocular rivalry occurs when two eyes receive conflicting information, leading to perceptual alternations between two eyes' images. The locus of binocular rivalry has received intense investigation as it is pertinent to the mechanisms of visual awareness. Here we assessed the functional stage of binocular rivalry relative to blind spot filling-in. Blind spot filling-in is thought to transpire in V1, providing a reference point for the locus of rivalry. We conducted two experiments to explore the functional order of binocular rivalry and blind spot filling-in. Experiment 1 examined if the information filled-in at the blind spot can engage in rivalry with a physical stimulus at the corresponding location in the fellow eye. Resulting perceptual reports showed no difference between this condition and a condition where filling-in was precluded by presenting the same stimuli away from the blind spot, suggesting that the rivalry process is not influenced by any filling-in that might occur. In Experiment 2, we paired the fellow eye's rival stimulus, not with the filled-in surface at the blind spot, but with the 'inducer' that immediately surrounds the blind spot and that engenders filling-in. We also established two control conditions away from the blind spot: one involving a ring physically identical to the inducer, and one involving a disk that resembled the filled-in percept. Perceptual reports in the blind spot condition resembled those in the former, 'ring' condition, more than those in the latter, 'disk' condition, indicating that a perceptually suppressed inducer does not engender filling-in. Our behavioral data suggest that binocular rivalry functionally precedes blind spot filling-in. We conjecture that binocular rivalry involves processing stages at or before V1, which would be consistent with views of binocular rivalry that involve low-level competition, and with evidence that binocular rivalry correlates can be found as early as the lateral geniculate nucleus.

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23.4055 The content of visual working memory alters processing of visual input prior to conscious access: evidence from pupillometry

Surya Gayet[1](s.gayet@uu.nl), Chris Paffen[1], Matthias Guggenmos[2], Philipp Sterzer[2], Stefan Van der Stigchel[1]; [1]Experimental Psychology, Utrecht University, Helmholtz Institute (Utrecht, The Netherlands), [2]Psychiatry and Psychotherapy, Charite University Medecine (Berlin, Germany)

Visual working memory (VWM) allows for keeping relevant visual information available after termination of its sensory input. Storing information in VWM, however, affects concurrent conscious perception of visual input: initially suppressed visual input gains prioritized access to consciousness when it matches the content of VWM (Gayet et al., 2013). Recently, there has been a debate whether such modulations of conscious access operate prior to conscious perception or, rather, during a transition period from non-conscious to conscious perception. Here, we used pupil size measurements to track the influence of VWM on visual input continuously, and dissociate between these possibilities. Participants were sequentially presented with two shapes drawn from different shape categories (ellipses, rectangles, or triangles) and a retro-cue, indicating which of the two shapes should be remembered for subsequent recall. During the retention interval, participants were instructed to report whether a target shape, which either matched or mismatched the concurrently memorized item, was presented left or right of fixation. Critically, the target shape was initially suppressed from consciousness by continuous flash suppression, and could therefore only be responded to once it was consciously accessible. Analyses of response times revealed that targets were released from suppression faster when they matched compared to when they mismatched the memorized shape. This behavioral effect was paralleled by a differential pupillary response such, that pupil constriction was more pronounced when visual input matched compared to when it mismatched the content of VWM. Importantly, this difference in pupil size emerged already 500ms after target onset, and almost two seconds before participants could report the location of the target shape. We conclude that the content of VWM affects processing of visual input when it is not yet consciously accessible, thereby allowing it to reach prioritized conscious access.

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23.4056 Access to awareness and semantic categories: low-level image properties drive access to awarenes

Sjoerd Stuit[1](s.m.stuit@uu.nl), Martijn Barendregt[2], Susan te Pas[1]; [1]Experimental Psychology, Utrecht University, [2]Experimental & Applied Psychology, Vrije Universiteit Amsterdam

Many social and visual research experiments have demonstrated behavioral effects based on semantic category differences, even when presented subliminally. For example, threatening faces reach awareness faster compared to neutral faces and naked human bodies attract attention when they match your sexual preference. Overall, images from categories that are relevant to an observer reach awareness faster compared to irrelevant images. However, a direct comparison of the processing of visual images from different semantic categories is complicated by the inherent differences in low-level image properties. Thus the question remains: is the time an image requires to reach awareness determined by the semantic category and its relevance or by low-level image properties? Here, we used a set of 400 pseudo-randomly selected images (from Google images) divided into four semantic categories (food, animals, art and naked human bodies) to test if access to awareness differs between categories when low-level image properties are taken into account. We used a breaking-continuous flash suppression paradigm to measure the amount of time an image takes to reach the observers awareness. Next, we extracted multiple indices of color and spatial frequency information from each images. Using a mixed-effects analysis we show that after taking image statistics into account, naked human bodies show no categorical effect on access to awareness. However, images of animals still result in deviating access to awareness rate compared to all other categories. Taken together, we show that most of the variance in access to awareness is in fact due to differences in low-level image properties. In particular, we find that differences in the spatial frequency content of the target image and that of the interocular mask strongly predict the variance in access to awareness. Our result demonstrate the importance of taking image statistics into account before comparing semantic categories.

23.4057 The effect of trypophobic images on conscious awareness during continuous flash suppression

Risako Shirai[1](RisakoShirai@kwansei.ac.jp), Hirokazu Ogawa[1]; [1]Department of Integrated Psychological Sciences, Kwansei Gakuin University

Trypophobia is a fear of clustered objects like lotus seed heads. Trypophobic objects do not involve dangerous objects, but they are a source of discomfort. Recently, Cole and Wilkins (2013) demonstrated that such trypophobic images contained excess energy at a particular range of spatial frequencies and claimed the unique power spectrums caused discomfort. In the present study, we examined whether the trypophobic unique power spectrums affect accessing to conscious awareness by using breaking continuous flash suppression (b-CFS) paradigm. In the b-CFS paradigm, the dynamic masking pattern is presented to one eye, which can suppresses the awareness for a target image presented to other eye until the target image breaks the suppression. The target images consisted of trypophobic, fear-related, hole or neutral scenes. All target images were original in intact-image condition, while the target images were converted to phase scrambled images in phase-scrambled-image condition. In both condition, participants were instructed to press a left or right key to indicate where the target image appeared on the display. The results showed that the fear-related and hole images emerged into awareness faster than the neutral images in intact-image condition. Moreover, the trypophobic images emerged into awareness faster than neutral, fear-related and hole images.

However, the phase-scrambled versions of the trypophobic images did not show any differences between the image types. These results showed that the trypophobic unique power spectrums did not affect the conscious awareness. Furthermore, we assessed what factors contributed to creating the benefit of trypophobic images on awareness using multiple regression analysis. The results showed that the benefit of trypophobic images on awareness was predicted by the benefit of hole and fear-related images on awareness. Taken together, the individual cognitive processes of trypophobic images might be explained by how much the processes of the simple geometric shape and emotion were facilitated.

23.4058 **Dissociating the Effects of Relevance and Predictability on Visual Detection Sensitivity** Roy Moyal[1](rm875@cornell.edu), Shimon Edelman[1]; [1]Department of Psychology, College of Arts and Sciences, Cornell University

When confronted with familiar tasks, people draw upon past experience to anticipate sensory input and optimize their performance. While it is uncontroversial that predictions influence perception, their effects on visual detection sensitivity are debatable; some studies suggest that surprise facilitates detection, whereas others show the opposite effect. These seemingly contradictory findings might be attributable to interactions between the relevance and the predictability of the stimuli used. To clarify the effects of expectation on visual detection sensitivity and dissociate them from those of relevance cues and primes, we conducted two continuous flash suppression experiments. In each trial, participants viewed a thin gray bar in one eye and an animated rectangular patch in the other eye. Expectation was manipulated by the inclusion of a cue, which predicted (with 80% validity) the orientation of the bar in half of the trials. In the first experiment, participants were asked to quickly press a key only if they detected a bar of a certain orientation (the relevance manipulation). In the second experiment, the cues were identical to the targets predicted by them in half of the trials; in the remaining trials, colored circles were used instead (the cue type manipulation). When the masked bar did not warrant a response, detection performance was poorer (in terms of both visibility reports and localization performance) in invalid cue trials relative to both valid cue and nonpredictive cue trials. These differences were absent when the presented stimulus was behaviorally relevant. Primes and abstract predictive cues, when valid, improved detection performance to similar extents. Our results suggest that, when both are at play, the effects of attentional priorities on visual detection thresholds override those of prior expectations. They also indicate that predictive cueing and repetition priming may rely on similar neural mechanisms.

Binocular Vision: Other

Saturday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4059 **Interocular interactions in macaque LGN** Kacie Dougherty[1](kacie.dougherty@vanderbilt.edu), Michele Cox[1], Jacob Westerberg[1], Alexander Maier[1]; [1]Department of Psychology, College of Arts and Science, Vanderbilt Unversity

Some of the most common visual disorders, such as amblyopia and stereoblindness, affect binocular vision. However, our understanding of how the brain processes binocular inputs is limited. Here we investigate where the signals from the two eyes first interact in the primary visual pathway in primates with normal binocular vision. The LGN is the first structure in this pathway receiving inputs from both eyes, with neighboring layers receiving exclusive inputs from one retina or the other. While the vast majority of neurons in the LGN are driven by stimulation of one eye only, it is unclear to what degree responses of LGN neurons depend on what is viewed by both eyes. In the primary visual cortex (V1), the next stage in the primary visual pathway, the vast majority of neurons respond to either eye, with one eye often evoking stronger responses than the other. In this study, we test the hypothesis that interocular interactions occur prior to spiking in V1. We trained macaque monkeys to fixate on a computer screen. Using a linear multicontact electrode array, we recorded LGN spiking responses to drifting gratings that varied in contrast and were presented to one or both eyes. Then, we compared contrast response functions under monocular and binocular stimulation conditions. We observed that the firing rate of a minority of LGN neurons, exclusive to the magnocellular layers, modulated under binocular stimulation. These effects included both binocular suppression and facilitation. We will discuss these results with regard to interocular anatomical connections in the primate early visual system.

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23.4060 **Overestimation of the number of elements in a three-dimensional stimulus is dependent on the size of the area containing the elements** Yusuke Matsuda[1](ymatsu1@kaiyodai.ac.jp), Koichi Shimono[1], Saori Aida[2]; [1]Faculty of Marine Technology, Tokyo University of Marine Science and Technology, [2]School of Computer Science, Tokyo University of Technology

Numerosity perception has been intensively examined using two-dimensional (2-D) stimuli, but has almost never been investigated using three-dimensional (3-D) stimuli. Recently, however, it was reported that a stereoscopic 3-D stimulus is perceived to have more elements than a stereoscopic 2-D stimulus when both contain the same number of elements. This suggests that the depth structure of the stimulus plays a role in numerosity perception. We examined the effect of the size of the area containing the elements on the overestimation phenomenon, using random-dot stereograms for 3-D and 2-D stimuli, which consisted of black square elements (6.7 * 6.7 arcmin) scattered in a circular area (4.4, 8.9, or 13.3 arcdeg in diameter). When the stereograms were fused, the 3-D and 2-D stimuli were perceived to have two transparent surfaces and a single surface, respectively. Observers performed a numerosity discrimination task, where they identified which of the two stimuli (presented side-by-side) had a greater number of elements. The number of elements was maintained constant at 50, 100, or 150 for the 3-D stimulus and varied for the 2-D stimulus to calculate the Weber fraction as an index of the degree of numerosity overestimation for the 3-D stimulus. The results indicated that the Weber fraction increases with the size of the circular area and the number of elements. The results can be explained in terms of a process or processes, with an output representing the perceived numerosity. The process(es) loads the visual system more heavily when the observer estimates the number of elements scattered in a 3-D space than when a single surface is estimated. This results in the overestimation of the elements in the 3-D stimuli.

23.4061 **Binocular contrast interactions in cross- and iso-oriented surround modulation: measurement and modeling** Pi-Chun Huang[1](pichun_huang@mail.ncku.edu.tw); [1]Department of Psychology, National Cheng Kung University

The detectability and discrimination abilities of a visual target can be improved or impaired by its surround stimulus, which is termed center-surround modulation. However, it is yet unclear whether or not surround modulation can occurs before or only after the binocular integration stage. In response, the pattern-masking paradigm was adopted to systematically measure the detection threshold of a target (horizontal Gabor, 2 cpd) under various pedestal contrasts and two surround contrasts (0 and 0.4), and with monocular, binocular and dichoptic viewing conditions. We also compared the modulation effects when the surround orientation was in parallel or orthogonal to the target orientation. With the monocular and dichoptic viewing conditions, the results showed that surround facilitation occurred at low pedestal contrast when the target and the surround mask were presented to the same eye; in contrast, surround suppression occurred at low pedestal contrast when the target and mask were presented to different eyes regardless of the pedestal's eye origin. With the binocular viewing condition, the surround modulation disappeared. To further investigate this phenomenon, the surround modulation effects under different combinations of eye origin were fitted with a two-stage binocular contrast-gain control model. The model not only successfully described the results, but also demonstrated that the surround modulation occurred before binocular summation, with interocular suppression also being involved. Furthermore, surround modulation was better modeled by using the multiplicative excitatory and multiplicative suppressive factors at the monocular level, but linearly added for interocular influence. Thus the role of surround modulation was to raise the gain of the spatial filter at the monocular level.

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Saturday AM

23.4062 Binocular Combination: Data and Binocular Perceptual Template Model
Chang-Bing Huang[1,3](huangcb@psych.ac.cn), Ge Chen[1,2,3], Fang Hou[4], Zhong-Lin Lu[5]; [1]CAS Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, 16 LinCui Rd, ChaoyangDist, Beijing 100101, China., [2]University of Chinese Academy of Sciences, Beijing, China, [3]Visual Information Processing and Learning Lab (VisPal), Institute of Psychology, CAS, Beijing, China, [4]School of Ophthalmology and Optometry and Eye Hospital, Wenzhou Medical University, Wenzhou, Zhejiang, China, [5]Center for Cognitive and Brain Sciences, Department of Psychology, Ohio State University, 225 Psychology Building, 1835 Neil Avenue Columbus, Ohio 43210, USA.

We have two eyes but only see one world. How visual inputs from the two eyes combine in binocular vision has been one of the major focuses in basic and clinical vision research. Here, we employed the external noise approach with dichoptic displays to develop a binocular perceptual template model (bPTM) based on multi-pathway contrast-gain control model and the perceptual template model. The method of constant stimuli was used to measure psychometric functions in a sinewave grating detection task in two spatial frequencies, three external noise levels, seven contrast levels, and four dichoptic and one binocular conditions. There were a total of 210 conditions and 18900 trials (90 trials/condition). We found that the threshold versus external noise contrast function (TvC) in the four dichoptic conditions were virtually identical, and were only higher than that of the binocular condition in zero and low external noise conditions. The thresholds in the highest external noise conditions were virtually identical across all five display conditions. We propose a binocular perceptual template model that consists of monocular perceptual templates, non-linear transducer, and internal noises, interocular contrast-gain control, binocular summation, binocular internal noise, and decision process. The model is compatible with the original PTM in binocular conditions, and the MCM developed for suprathreshold phase and contrast combination and stereopsis. With only five parameters, the bPTM provided an excellent account of all the data ($r^2 > 90\%$). With one additional parameter, the model can take into account of the imbalances between the two eyes in near threshold tasks, complementing the multi-pathway contrast gain control model in suprathreshold tasks. The empirical results and bPTM shed new light on binocular combination and may provide the basis to investigate binocular vision in clinical populations.

23.4063 Real-time experimental control with graphical user interface (REC-GUI) for vision research
Ari Rosenberg[1](ari.rosenberg@wisc.edu), Byounghoon Kim[1], Shobha Kenchappa[1], Ting-Yu Chang[1]; [1]Department of Neuroscience, School of Medicine and Public Health, University of Wisconsin-Madison, Madison, WI, USA

Vision science studies often involve a combination of behavioral control, stimulus rendering/presentation, and precisely timed measurements of electrophysiological and/or behavioral responses. The constraints imposed by these various requirements can make it challenging to jointly satisfy all the necessary design specifications for experimental control systems. Since precise knowledge of the temporal relationships between behavioral and neuronal data is fundamental to understanding brain function, we are spearheading an open-source, flexible software suite for implementing behavioral control, high precision control of stimulus presentation, and electrophysiological recordings. The state-of-the-art system is being developed to implement highly demanding specifications (e.g., rendering geometrically correct stereoscopic images with large depth variations, binocular stimulus presentation at 240 Hz, and real-time enforcement of behavior such as binocular eye and head positions), making the system ideally suited for a broad range of vision studies. The Real-Time Experimental Control with Graphical User Interface (REC-GUI) consists of three major components: (i) experimenter control panel (Python), (ii) scripts for rendering 2D or 3D visual stimuli (MATLAB/Octave with PsychToolbox), and (iii) data acquisition components including eye/head monitoring (search coil: Crist Instruments; optical: EyeLink, SR-Research Inc.) and high-density neural recording (Scout Processor, Ripple Inc.). Because rendering and presenting complex visual stimuli like 3D stereoscopic images can require significant computing power capable of interrupting display synchronization, the system divides stimulus rendering/presentation and behavioral control between different processors. All processors communicate with each other over a network in real-time using User Datagram Protocol to minimize communication delays (average 767 ± 260 μsec over a gigabyte network switch). Because the system is modular, all components can be easily substituted to be compatible with different software, hardware, and data acquisition systems. For example, MATLAB-based stimulus rendering/presentation can be readily replaced with C-code. We will soon make all of the MATLAB/Octave and Python scripts available for customization and collaborative development.

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23.4064 Interocular enhancement revealed in binocular combination
Jian Ding[1](jian.ding@berkeley.edu), Oren Yehezkel[1], Anna Sterkin[2], Uri Polat[3], Dennis Levi[1]; [1]School of Optometry, UC Berkeley , [2]Goldschleger Eye Research Institute, Sackler Faculty of Medicine, Tel Aviv University, [3]Faculty of Life Sciences, Optometry and Vision Sciences, Bar-Ilan University

Interocular suppression has been demonstrated in multiple binocular tasks. However evidence for interocular enhancement has been elusive, because, in the normal visual system, it is concealed by the strong interocular suppression. Interocular enhancement was first exposed in a study on amblyopic binocular vision (Ding, Klein & Levi 2013b) where the interocular suppression from the non-dominant eye to the dominant eye is almost absent, thus revealing interocular enhancement. For normal binocular vision, adding interocular enhancement to a gain-control model (Ding-Sperling model, Ding & Sperling 2006) results in significant improvement in model fitting in binocular phase and contrast combination tasks (Ding, Klein & Levi 2013a), and in binocular contrast discrimination (Ding & Levi 2016). In the present study, we examined how normally sighted observers combine slightly different orientations presented to the two eyes. The stimuli were briefly presented (80 ms) Gabor patches (3 cpd) presented to the two eyes, which differed in both orientation and contrast. We used a signal-detection rating method to estimate the perceived orientation. We tested three orientation differences (10, 15 and 20 degrees), four base contrasts (10, 20, 40, and 60%) and seven interocular (dichoptic) contrast ratios (0.25, 0.5, 0.75, 1, 1.33, 2, and 4). We found that the interocular suppression decreased when the base contrast increased, contradicting the prediction (more suppression at a higher contrast level) of the Ding-Sperling model. Our modeling showed that interocular enhancement is needed to neutralize the effect of interocular suppression when the base contrast increased. By adding interocular enhancement to the Ding-Sperling model, the modified model successfully accounted for whole data set. Combined with interocular suppression, interocular enhancement appears to play an important role in binocular vision.

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23.4065 A contrast-based Pulfrich effect in normals and a spontaneous Pulfrich effect in amblyopes
Alexandre Reynaud[1](alexandre.reynaud@mcgill.ca), Robert Hess[1]; [1]McGill Vision Research, Dept of Ophthalmology, McGill University

Any processing delay between the two eyes can result in illusory 3D percepts for moving objects because of either changes in the pure disparities over time for disparity sensors or by changes to sensors that encode motion/disparity conjointly. This is demonstrated by viewing a fronto-parallel pendulum through a neutral density (ND) filter placed over one eye, resulting in the illusory 3D percept of the pendulum following an elliptical orbit in depth, the so-called Pulfrich phenomenon. Because of the difference between their two eyes, a small percentage (4%) of mild anisometropic amblyopes who have rudimentary stereo are known to experience a spontaneous Pulfrich phenomenon. Here we use a paradigm where a cylinder rotating in depth, defined by moving Gabor patches is presented at different interocular phases, generating strong to ambiguous depth percepts. This paradigm allows one to manipulate independently the spatio-temporal properties of the patches to determine their influence on perceived motion-in-depth. We show psychophysically that an interocular contrast difference can itself result in a similar illusory 3D percept of motion-in-depth. For amblyopes we observe a spontaneous Pulfrich phenomenon but opposite to that expected, suggesting a faster processing by the amblyopic eye. This spontaneous delay is reduced at low spatial and temporal fre-

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quencies. We conclude that spatio temporal properties of the stimuli are important for the illusion of motion-in-depth from contrast differences or the spontaneous Pulfrich experienced by some amblyopes.

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23.4066 The impact of object-based grouping on perceived depth magnitude: Virtual vs. physical targets Aishwarya Sudhama[1](ash10@my.yorku.ca), Lesley Deas[2], Brittney Hartle[2], Matthew Cutone[2], Laurie Wilcox[2]; [1]Department of Biology, Centre for Vision Research, York University, [2]Department of Psychology, Centre for Vision Research, York University

The amount of depth perceived between two vertical lines is markedly reduced when those lines are connected to form the boundaries of a uniform closed object (Deas & Wilcox, 2014). Recently, we suggested that this degraded depth effect is contingent on perceptual grouping of elements to form an object and on disparity changes along the horizontal axis (Sudhama et al., 2015 VSS). In previous studies stimuli were presented virtually on LCD displays, using a mirror stereoscope. In this set of experiments, we ask whether the same distortions in perceived depth are observed when multiple, consistent 2D depth cues are present. Here, we replicated Deas and Wilcox's original paradigm using physical stimuli. Targets consisted of 3D-printed vertical posts (in isolation and connected to form rectangles), mounted on a customized computer-controlled motion platform. Stimuli were printed with a range of horizontal disparities between the vertical contours. The stimulus dimensions, viewing distance, and test manipulations closely matched the original paradigm. A set of four disparities was tested ten times apiece in random order, for isolated and connected stimuli. On each trial, observers judged the amount of depth between two vertical posts using a touch sensitive strip. We found that the resulting depth magnitude estimates were accurate over a large range of disparities. Moreover, there was no difference between estimates obtained in the isolated line vs. closed object configurations. In follow-up experiments with virtual targets we also found that the disruptive effects of perceptual grouping are modulated by the presence of multiple depth cues. We argue that this is not due to conflicts between 2D and stereoscopic depth cues. Instead, the absence of reliable additional depth cues makes stereoscopic depth estimates more susceptible to phenomena such as object-based grouping. These results have clear implications for creation and use of stereoscopic imagery in virtual environments.

Acknowledgement: NSERC Discovery and CREATE Grants

23.4067 Visual Discomfort and Ethnicity Robert Mosher[1](robert.mosher.176@my.csun.edu), Daniel Del Cid[1], Arthur Ilnicki[1], Stefanie Drew[1]; [1]Vision Sciences, College of Social and Behavioral Sciences, California State University Northridge

Ethnic differences in prevalence of visual impairment have been reported in children but this distinction has been less studied in college age adults (Kleinstein, 2003). Other research suggests an overall 16.8% prevalence of myopia in the Latino population (Tarczy-Hornoch, 2006). We previously noted a high incidence of visual discomfort symptoms reported by a diverse population of college students. These findings were expected, as symptoms including ocular fatigue, perceptual distortions, and headaches are linked to nearwork tasks commonly performed by students, such as reading or viewing computer screens. Based on ethnic-specific prevalence of myopia noted by other studies we investigated whether similar patterns might be observed in reports of visual discomfort symptoms in college students. Methods: Two validated surveys for assessing visual discomfort symptoms, the Visual Discomfort Survey (VDS) (Conlon et al., 1999) and the Convergence Insufficiency Symptoms Survey (CISS) (Borsting et al., 2003), and demographic questions were administered to 451 college students. Results: Participants who identified as Latino/a or Hispanic showed significantly different patterns of results in a mediation model than those that identified as Non-Latio/a or Non-Hispanic. These findings suggest prevalence of visual discomfort in the college population may be confounded by ethnic differences.

23.4068 Does an eye movement make the difference in 3D? Katharina Rifai[1](katharina.rifai@medizin.uni-tuebingen.de), Siegfried Wahl[1]; [1]Institute for Ophthalmic research, University of Tuebingen

Currently, stereo image presentation is still the dominant commercially used 3D image presentation technology. Widely applied in cinematic applications, gaming, and optical technologies, adverse effects such as fatigue, vertigo, and nausea are well described. However, the origin of those adverse effects is relatively sparsely explored, partially due to technological difficulties in disentangling influencing factors. Stereographic image content commonly varies from real world visual input in a variety of ways. Specifically, in most applications the influence of the observer's eye remains unconsidered. Thus neither accommodation nor changes in image projection due to eye movements are accurately mirrored in stereoscopic 3D image content. In the current study, task performance as well as a subjective experience is assessed in a video-based stereo imaging system, in which the visual impact of accommodation as well as image projection changes due to eye movements can selectively be enabled. In four conditions (ACC accommodation, EM eye movements, ACC&EM, STATIC) subjects performed a time-limited manual accuracy task. Subjects collected pins from predefined touch points with forceps. Task performance was measured by the amount of collected pins per time and compared between the four conditions. Subjective experience was evaluated in a customized questionnaire, and compared to task performance. In the questionnaire task difficulty, experienced depth, immersion, and adverse reactions were analyzed. Thus, the presented study considers the dedicated influences of accommodation and eye movements in 3D perception of stereographic video content. The results shed light on the relevance of active vision in the perception of depth.

Acknowledgement: This project has been founded by the Inter-University Center for Medical Technologies Stuttgart – Tübingen (IZST) and Carl Zeiss Meditec AG.

23.4069 A Bayesian model of distance perception from ocular convergence Peter Scarfe[1](p.scarfe@reading.ac.uk), Paul Hibbard[2]; [1]School of Psychology and Clinical Language Sciences, University of Reading, UK, [2]Department of Psychology, University of Essex, UK

When estimating distance from ocular convergence humans make systematic errors such that perceived distance is a progressive underestimate of true physical distance. Similarly, when estimating the shape of an object from binocular visual cues, object depth is progressively underestimated with increasing distance. Misestimates of distance are thought to be key to explaining this lack of shape constancy. Here we present a Bayesian model of distance perception from ocular convergence which predicts these biases given the assumption that the brain is trying to estimate the most likely distance to have produced the measured, noisy, ocular convergence signal. We show that there is a lawful relationship between the magnitude of noise in the ocular convergence signal and the magnitude of perceptual bias (more noise results in greater bias). Furthermore, using a database of laser scans of natural objects, we generate prior probabilities of distances in the environment and show how these priors are distorted by the process of distance estimation, such that the perceptual prior based on distance estimates is not necessarily equal to the objectively measured distance prior in the world. This has important implications for defining perceptual priors based on direct statistical measurements of the environment across multiple disciplines.

23.4070 Fusional Vergence differences between manual phoropter and automated phoropter Efrain Castellanos[1](ecastellanos@westernu.edu), Kevin Phan[1]; [1]Western University College of Optometry

Purpose: The use of automated phoropters is becoming common in ophthalmic clinics however "the clinical norms" utilized for evaluating vergences were obtained using the manual phoropter. We sought to investigate and compare the fusional vergence findings obtained with the automated phoropter (Nidek RT-5100) and the manual phoropter (Topcon). Methods: The study was conducted at the College of Optometry at Western University of Health Sciences, Pomona California where a total of 188 participants (optometry students) who were paired and individuals examined each other and performed vergence measurements. The vergence measurement was performed for both distance vision (20 feet) and near vision (40 centimeters) using the 1) manual phoropter 2) automated phoropter. The sequence of measurement was randomized. Results: A paired samples t-test was utilized to evaluate the vergence data of blur/ break and recovery was analyzed for each method using paired samples t-test. The mean values of blur/break and recovery was significantly different between the two phoropters at 20 feet p-values of 0.006, 0.013, and 0.002 respectively. At near distance (40 cms) convergence base out showed significant difference for recovery (p= < 0.0001) and divergence base in prism for break in fusional vergence (p=0.006). Conclusion: The vergence values obtained using an automated phoropter is significantly different when compared to values obtained using manual phoropter and the results obtained using these phoropters cannot be used interchangeably. Clinicians need to take this into account when making any clinical judgement involving any prism prescription. A new set of clinical norms might be needed as a clinical guideline when evaluating patients using automated phoropters.

23.4071 **Modulation of oculomotor control & adaptation with cerebellar TMS: effects on slow-tonic vergence adaptation.** Heidi Patterson[1](hepatter@uwaterloo.ca), Ian Erkelens[1], Claudia Martin Calderon[1], William Bobier[1], Benjamin Thompson[1,2]; [1]University of Waterloo, School of Optometry & Vision Science, [2]University of Auckland, School of Optometry & Vision Science

The adaptation of heterophoria to horizontal base-out prism reflects a slow change in the underlying tonic vergence neural innervation. Recent fMRI evidence suggests the posterior cerebellum may play a role in this unique adaptive process. We applied continuous theta-bust stimulation (cTBS) to the oculomotor vermis (OMV) of the posterior cerebellum to investigate a causal relationship between this neural structure and slow-tonic vergence (STV) adaptation. 14 subjects fused a 0.18 LogMAR chart at 40cm through a 15 prism diopter (PD) base-out prism for 4 minutes after receiving active or sham cTBS stimulation (3-50Hz pulses at 200ms intervals for 40 seconds) to the OMV over the posterior cerebellum. Change in heterophoria, measured with Modified Thornington Technique every 15 seconds, defined the amplitude and rate of STV adaptation. cTBS was applied at 80% of the individual's active motor threshold via a 2x75mm butterfly coil. Stimulation sites were localized using the BrainSight® neuro-navigation system and anatomical landmarks. The amplitude of STV adaptation was not different between active (6.31 ± 0.40 PD) and sham (6.97 ± 0.41 PD) conditions, p = 0.18. There was also no difference between the maximum rate of tonic vergence adaptation in the active (0.41 ± 0.07 PD/s) or sham (0.33 ± 0.05 PD/s) conditions, p = 0.18. Baseline levels of tonic vergence innervation, measured before and after stimulation at each visit, were not different between conditions (p > 0.15). cTBS applied to the OMV of the posterior cerebellum did not affect tonic vergence innervation or STV adaptation to base-out prism in healthy controls. This is in contrast to other types of oculomotor adaptation, where cTBS has been shown to affect both reflexive pro-saccade generation and adaptation to double step stimuli. These results suggest the OMV of the posterior cerebellum plays a limited role in the management and adaptation of tonic vergence neural innervation.

Acknowledgement: NSERC, OGS, COETF

23.4072 **A computational model for the joint development of accommodation and vergence control** Jochen Triesch[1](triesch@fias.uni-frankfurt.de), Samuel Eckmann[1], Bertram Shi[2]; [1]Frankfurt Institute for Advanced Studies, [2]Dept. of Electronic and Computer Engineering, Hong Kong University of Science and Technology

Several studies investigating the development of amblyopia and strabismus suggest a strong interaction between vergence and accommodation. For example, patients suffering from strabismus often develop amblyopia and subjects with amblyopia show decreased vergence and accommodation performance. Here we present the first computational model for the joint development of accommodation and vergence control in the active efficient coding framework. We use an online sparse coding algorithm to learn binocular receptive fields similar to those in V1 simple cells. These adapt online to the input statistics by maximizing coding efficiency. Simultaneously, the learned sparse representation is used to determine the reward for two actor-critic reinforcement learners (RLs), which control accommodation and vergence, respectively. By optimizing coding complexity (for accommodation control) and efficiency (for vergence control) the system learns to focus images with zero disparity under healthy conditions. Interestingly, the accommodation RL learns to deduce the correct command from the input disparity. We simulate an anisometropic case where the refraction power of one eye is decreased. In this situation our model chooses to focus close objects with the healthy and distant objects with the hyperopic eye. Vergence performance remains high as long as the refraction difference stays small. However, when focusing the object with one eye leads to a highly blurred input for the other eye, the receptive fields become more and more monocular. Thus, the RLs are no longer able to assess the exact input disparity, which ultimately leads to a decrease of both the vergence and accommodation performance. In conclusion, we present, to the best of our knowledge, the first model for the joint learning of vergence and accommodation control. The model explains how the brain might learn to exploit disparity signals to control both vergence and accommodation and how refractive errors could derail this process.

Acknowledgement: This research is supported by the project

Perceptual Organization: Grouping

Saturday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4073 **Inter-Edge Grouping: Are many figure-ground principles actually perceptual grouping?** Joseph Brooks[1](j.l.brooks@kent.ac.uk), Anka Davila[1], Akul Satish[1]; [1]Centre for Cognitive Neuroscience & Cognitive Systems, School of Psychology, University of Kent

Figure-ground organization (a.k.a. edge-assignment) determines the shapes that we see at edges and is widely known through experience of Rubin's reversible faces-vase image. It is thought to be affected by a host of image-based (e.g., convexity) and non-image factors (e.g., attention, familiarity). Figure-ground organization often appears alongside perceptual grouping as a topic in psychology textbooks but they are typically discussed as separate processes of perceptual organization with their own distinct phenomena and mechanisms. Here, we propose a new class of figure-ground principles based on perceptual grouping between edges and demonstrate that this inter-edge grouping (IEG) is a powerful influence on figure-ground organization. We presented participants with tri-partite images with two vertical dividing edges creating a central region and two flanking regions (e.g., Rubin's faces-vase). The two dividing edges were either grouped or ungrouped according to one of seven different grouping principles (e.g., colour similarity, common fate). We measured figure-ground organization of these tri-partite images (e.g., inner or flanking regions figural) using both subjective reports and an objective, indirect measure of figure-ground organization. Across all grouping principles and both measures, we found that figure-ground organization was affected by IEG such that the central region between the two edges was more likely to be reported as figural when the edges were grouped whereas the flanking regions were reported as figural with ungrouped edges. In addition to these new phenomena, we can also describe some classic figure-ground principles under the same coherent framework. For instance, symmetry in multi-partite displays can be reinterpreted as inter-edge symmetry and convexity effects on figure-ground may be partially due to inter-edge good continuation. Our results suggest that figure-ground organization and grouping have more than a mere association within Gestalt psychology. Instead, perceptual grouping may provide a mechanism underlying a broad class of new and extant figure-ground principles.

Acknowledgement: Experimental Psychology Society Small Grant

23.4074 **The mechanism underlying the competition between grouping organizations** Einat Rashal[1](einatrashal@gmail.com), Michael Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland

Most previous investigations studied the competition between grouping principles using subjective reports. Recently, Rashal, Yeshurun and Kimchi (2016) used the primed-matching paradigm to investigate the time-course of this competition. In this paradigm, a prime stimulus is followed by a pair of test figures that are either identical to one another or different. Typically, "same" responses to the test-pair are faster and/or more accurate when they are similar to the prime than when they are dissimilar. In that study, the primes depicted one grouping principle, or two principles that led to different organizations (e.g., columns by brightness simmilarity and rows by proximity). Their results showed that at certain points of the time-course both organizations produced similar priming, suggesting that representations of both organizations are constructed, and presumably compete before the final percept is chosen for conscious perception. In the current study, we examined whether the time-course of the competition is affected by grouping strength. To that end, we manipulated the degree of the elements' similarity for each grouping principle in the prime. Priming effects

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were expected to emerge for the organization that produces stronger priming relative to the other (i.e., the dominant organization). The time-course of the competition was examined by varying prime duration. We found that priming effects for the dominant organization increased as grouping strength increased for that organization. However, priming was also reduced for the dominant organization as grouping strength for the second organization increased. These results further support previous findings of a competition between multiple representations, and provide evidence for grouping strength as a factor in this competition.

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23.4075 Estimating the relative strength of similarity and proximity in perceptual grouping with tripole Glass patterns Chien-Chung Chen[1,2](c3chen@ntu.edu.tw), Lee Lin[1], Yih-Shiuan Lin[1]; [1]Department of Psychology, National Taiwan University, [2]Neurobiology and Cognitive Science Center, National Taiwan University

In Gestalt tradition, proximity and similarity are important cues for perceptual organization. We investigated how the visual system integrates these cues by measuring their relative strength when they produced conflicting grouping signals. We used tripole Glass pattern (tGP) which composed of randomly distributed sets of three dots, including a seed and two context dots. The tripoles were arranged in a way that linking the seed with one context dot would produce a percept of clockwise (CW) spiral while the other, counter-clockwise (CCW) spiral. The contrast of context ranged from -30 to 0dB while the seed contrast kept at -20dB. The distance between the seed and the context dots were between 5 and 20 min. The observers' task was to indicate whether the tGP they perceived in each trial was CW or CCW. When the distance between the seed and the two context dots were the same, the probability of seeing CW spiral first increased and then decreased with CW dot contrast, forming an Inverted-U shape psychometric function. The peak of the inverted-U function shifted rightward as CCW dot contrast increased. When all dots had the same contrast, it was 10-20% more likely to see the pattern formed by linking seed and the context dot at a half distance than the other dot. Such proximity advantage was canceled by decreasing the contrast of the proximity dot by about 6dB (50%), suggesting a linear trade-off between proximity and contrast similarity. Our result cannot be accounted for either by similarity or contrast energy theories for Glass pattern, but was well fit by a pattern normalization model, in which the response of a pattern detector was the sum of the excitations of linear filters operating on local dipoles raised by a power and divided by an inhibition signals from all other dipoles.

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23.4076 Parallelism is an emergent feature not derived from the detection of individual line slopes James Pomerantz[1](pomeran@rice.edu), Curtiss Chapman[1], Jon Flynn[2], Colin Noe[1], Tian Yingxue[1]; [1]Department of Psychology, Rice University, [2]Neurobiology and Anatomy, UT Health Sciences Center Houston

Visual systems are quite sensitive to parallelism between two or more line segments, but how do they detect this feature? Many methods are possible, one of which includes computing and then comparing the slopes of the lines in a feedforward manner. If the visual system employs this method, it should be harder for us to perceive parallelism between two lines when they are oriented obliquely, compared with being horizontal or vertical, because of the oblique effect (OE; Appelle, 1972). Our experiment confirmed the expected OE for processing individual line segments, but we found a greatly reduced OE for processing pairs of parallel vs. nonparallel lines. We also demonstrated a sizeable configural superiority effect (CSE; Pomerantz, Sager, and Stoever, 1977) for line pairs over individual line segments. This CSE means it is easier to determine which of four line segments has a different slope from the other three identical segments when the same, non-informative line segment is added next to all four segments to create four pairs of segments, three pairs of which are parallel and one non-parallel (or vice versa). Our findings differed largely in expected ways when the stimuli were presented inside a diamond-shaped frame (sharing parallelism within the frame) rather than square: performance with oblique lines improved. In summary, our results suggest that parallelism is a salient emergent feature in vision, more salient to us than the slopes of the individual lines from which it arises. Parallelism appears to be detected through some method other than computing and comparing the slopes of the two line segments, perhaps by being detected directly. Parallelism thus joins other emergent features arising from line segments, including collinearity, intersection, closure, and symmetry, as an extremely salient higher-order property of wholes that is more perceptible are than the component parts from which it derives.

23.4077 Category-based updating of object representations Ru Qi Yu[1](ruqiyu@psych.ubc.ca), Jiaying Zhao[1,2]; [1]Department of Psychology, University of British Columbia, [2]Institute for Resources, Environment and Sustainability, University of British Columbia

The visual system is efficient at detecting regularities in the environment. When two objects reliably co-occur, changes in one object are automatically transferred to its co-occurring partner. It is unknown how such updating can transpire across categorical boundaries. In Experiment 1, participants viewed a random temporal stream of objects, which came from two distinct categories based on texture (i.e., objects in Category A had stripes vs. objects in Category B had dots). Each object had a unique shape. After exposure, one object in Category A (e.g., A1) increased in size, and participants recalled the size of another object in the same category (e.g., A2) or in the different category (e.g., B1). We found that objects in the same category were recalled to be reliably larger than objects in the different category, suggesting that changes in one object are more likely to be transferred to another in the same category than in an object in a different category. To elucidate if the cross-category transfer can be facilitated by statistical regularities, we conducted Experiment 2, where participants viewed the same objects, except now objects in the two categories were temporally paired (i.e., A1 reliably appeared before B1). After exposure, one object in Category A (e.g., A1) increased in size, and participants recalled the size of the cross-category paired partner (B1), the within-category random object (A2), or cross-category random object (B2). We found that the within-category object (A2) was recalled to be reliably larger than any cross-category object (B1 or B2). This suggests that changes in one object were more strongly transferred to other objects in the same category any objects of a different category, regardless of statistical regularities. These results reveal a within-category advantage of updating of feature changes, that they are more readily transferred within the same category than across categories.

23.4078 Solving the Complexity of Object Occlusions in Scenes: The Grouping of Adjacent Surfaces and Non-Adjacent but Connected Surfaces Debarshi Datta[1](ddatta2014@fau.edu), Howard Hock[1,2]; [1]Department of Psychology, Schmidt College of Science, Florida Atlantic University, [2]Center for Complex Systems and Brain Sciences, Schmidt College of Science, Florida Atlantic University

In contrast with classic Gestalt examples of perceptual grouping, most natural environments contain multiple objects, each with multiple surfaces. Each object is likely to occlude other objects partially and is itself likely to be partially occluded. A central question, therefore, is how the visual system resolves the resulting surface correspondence problem by successfully determining which surfaces belong to which objects (Guzman, 1969). To this end, a recently developed dynamic grouping methodology determines whether pairs of adjacent surfaces are grouped together (Hock & Nichols, 2012; Hock & Schöner, 2015). The grouping of adjacent surfaces, which depends on their affinity state, is indicated by the direction of perceived motion across one surface when its luminance (and thus, its luminance similarity with the adjacent surface) is perturbed. It is shown here that dynamic grouping also can occur for nonadjacent surfaces, providing they are linked in two-dimensions by a connecting surface. METHOD: Three disconnected horizontal surfaces with the same luminance are presented with two darker surfaces that connect them. Dynamic grouping motion is created by decreasing the central horizontal surface's luminance, decreasing its similarity with the flanking horizontal surfaces (while simultaneously increasing its similarity with the darker connecting surfaces). RESULTS: The perception of outward (diverging) dynamic grouping motion toward the flanking horizontal surfaces indicated that the central horizontal surface was grouped with the nonadjacent, but connected flanking horizontal surfaces. This was consistent with connectivity functioning as a grouping variable, which was first reported by Palmer and Rock (1994). Preliminary evidence indicates that the dynamic grouping motion is stronger when the nonadjacent but connected horizontal surfaces are aligned, and the

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connecting surfaces function as occluders (in this case dark vertical bars), consistent with amodal completion requiring the perceptual grouping of nonadjacent surfaces behind an occluding surface.

23.4079 **Evidence for Configural Superiority Effects in Convolutional Neural Networks** Shaiyan Keshvari[1](shaiyan@mit.edu), Ruth Rosenholtz[1,2]; [1]Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology, [2]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology

Finding a left-tilted line among right-tilted becomes easier with an "L" added to each item, transforming the task into one of finding a triangle among arrows. This configural superiority effect occurs for a wide array of stimuli, and is thought to result from vision utilizing "emergent" features (EFs), such as closure, in the composite case. A more computational interpretation can be couched in idea of a visual processing hierarchy, in which higher level representations support complex tasks at the expense of other, possibly less ecologically relevant tasks. Detecting the oddball might be inherently easier in the composite condition given the representation at some level of the hierarchy. To test this, we used the VGG-16 (Simonyan & Zisserman, 2015) convolutional neural network (CNN), trained to recognize objects using the ImageNet dataset, as a stand-in for the hierarchical visual encoding. Such CNNs have high performance on object recognition, as well as on tasks for which they are not trained. Feature vectors at different layers correlate with responses of various brain areas (Hong et al., 2015). We tested five EF stimuli in a 4AFC oddball localization task (Pomerantz & Cragin, 2013). We trained a multi-class SVM operating on the outputs of the last fully connected layer, and performed a K-fold cross-validation. Two EFs (orthogonality and roundness) show better performance (33 and 53 percentage points, respectively) in the composite than the base case. One (closure) showed no effect (< 1 pp), and two (parallelism and 3D) had worse performance in the composite (23 and 21 pp). A pilot behavioral experiment (200 ms presentation) confirmed that observers (N=2) are better with composite stimuli for all five EFs (44 +/- 0.06 pp). This suggests that some EFs are better represented by highest layers of the network than their base features, but it is not the complete story.

23.4080 **Can perceptual grouping unfold in the absence of visual consciousness?** Ruth Kimchi[1](rkimchi@research.haifa.ac.il), Dina Devyatko[1], Shahar Sabary[1]; [1]Department of Psychology and Institute of Information Processing and Decision making, University of Haifa

What kinds of perceptual organization can occur without awareness of the stimulus? Previous studies addressing this issue yielded inconsistent results (e.g., Harris et al., 2011; Lau & Cheung, 2012; Montoro et al., 2014; Moors et al., 2015; Wang et al., 2012). The inconsistency may be partly due to different techniques used to induce invisibility. In this study, we examined whether visual consciousness is required for two perceptual grouping principles: luminance similarity and element connectedness, using priming paradigm and the same technique — continuous flash suppression (CFS; Tsuchiya & Koch, 2005) — to render the prime invisible. Participants were presented with a liminal prime consisted of dots organized into rows or columns by luminance similarity (Experiment 1; 20 participants) or by element connectedness (Experiment 2; 19 participants), followed by a clearly visible target composed of lines, the orientation of which could be congruent or incongruent with the orientation of the prime. The prime-target SOA varied (200,400, 600, or 800 ms). On each trial participants made speeded discrimination response to the orientation of the target lines (vertical or horizontal) and then rated the visibility of the prime using a scale ranging from 0 ("I saw nothing") to 3 ("I clearly saw …"). Unconscious grouping of the prime was measured as the priming effect on target discrimination performance of prime-target orientation congruency, on trials in which participants reported no visibility of the prime. In both experiments, and across all prime-target SOA, there were no priming when the prime was reported invisible; significant priming was observed when the prime was reported visible. These findings suggest that perceptual grouping by luminance similarity and by element connectedness does not take place when the visual stimulus is rendered nonconscious using CFS.

Acknowledgement: ISF

23.4081 **1,2,3, many: Perceptual order is computed by patches containing 3x3 "repetitions" of Motifs** Mikhail Katkov[1](mikhail.katkov@gmail.com), Hila Harris[1], Dov Sagi[1]; [1]Department of Neurobiology, Weizmann Institute of Science, Rehovot, 76100 Israel

It is believed that symmetry plays an important role in human visual perception, as is manifested by the Gestalt laws. Mathematically, symmetry is defined as a transformation mapping an image to itself. An important class of such transformations is the Wallpaper Group that consists of repetitive patterns (Motifs). Strict symmetry rarely appears in nature. In statistical physics the deviation from symmetry is characterized by the Order Parameter, ranging from zero (random) to one (symmetry). Operationally, it is usually defined as the first order statistic over a local symmetry measure. Here we are interested in estimating the size of the local symmetry measure in the human visual system, defined in terms of the number of Motif repetitions. We used a 4AFC spatial odd-ball discrimination task: three quadrants of stimulus contained randomly generated textures, whereas the fourth quadrant contained a texture with varying degree of order. Order was controlled by the thermodynamic temperature in a Boltzmann distribution with potentials having different symmetries. Images were generated by a Chromatic Gibbs Sampler. Motif size was NxM Gaussian blobs (N=7-9, M=7-9 depending on the symmetry of the potential). Results from 4 observers show that psychometric functions (discrimination performance vs. temperature) were not different between images trimmed to size of 3x3 motifs and larger images, whereas discrimination of images of one motif size was practically at chance level for all temperatures. Images of 2x2 motifs were in between (at high temperatures these patches do not have obvious repetitions). Importantly, scaling the trimmed images leads to the same performance. We conclude from these results that if order is computed in the brain it is performed by patches containing 3x3 motifs. Moreover, the amount of the information in the patches, and not the physical size, is important for order perception.

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23.4082 **Examining a shift in response bias through two lenses: A concurrent examination of process and informational characteristics** Michael Wenger[1](michael.j.wenger@ou.edu), Lisa DeStefano[1], James Townsend[2], Yanjun Liu[2], Ru Zhang[3]; [1]Psychology, Cellular and Behavioral Neurobiology, The University of Oklahoma, [2]Psychological and Brain Sciences, Indiana University, [3]University of Colorado Boulder

Critical distinctions in human information processing, such as parallel versus serial processing, or integral versus separable dimensions of encoded information, are at the very core of understanding the foundations of psychological experience. As such, two lines of general and powerful mathematical characterizations of these problems have been developed, resulting in two meta-theories: general recognition theory (GRT, Ashby & Townsend, 1986), which addresses the relations among multiple sources of encoded information using response frequencies, and systems factorial theory (SFT, Townsend & Nozawa, 1995), which addresses fundamental characteristics of processing using reaction times (RTs). To date, GRT and SFT have evolved separately, with open questions existing for each; the present effort is one of a set of ongoing efforts intended to address the questions of each meta-theory individually by using the two approaches together. In the present effort, we sought to investigate the extent to which a response bias could be reliably identified in both response frequencies and RTs, by using static GRT, a newer RT version of GRT (RTGRT, Townsend, Houpt, & Silbert, 2012) and SFT. The stimuli for this particular investigation were designed to induce the Hering illusion, where physically vertical lines to the left and right of a center point are superimposed on a set of radiating lines, resulting in the illusion that the vertical lines are bowed outward. Observers participated in two tasks, a double factorial task using a conjunctive (AND) response rule and a complete identification task. Payoff schemes were manipulated in a way that the optimal responding was first unbiased and then was biased toward specific responses. Results indicate that capacity increased with liberal bias and decreased with conservative bias. Individual differences across observers suggest the potential for using these regularities to advance a theoretical synthesis of the two approaches.

Acknowledgement: National Science Foundation

Perceptual Organization: Neural mechanisms

Saturday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4083 Neural representations of ensemble coding for visual features in the early visual and fronto-parietal cortex

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The human brain is endowed with the ability to summarize the properties of similar objects to efficiently represent a complex visual environment. Although previous behavioral studies demonstrated that we can extract the mean orientation, size and speed from sets of items (Ariely, 2001; Chong & Treisman, 2003; Dakin & Watt, 1997; Watamaniuk & Duchon, 1992), the underlying neural mechanism remains poorly understood. Here, we investigated the neural substrates of visual statistical summary representation. More specifically, using fMRI and encoding methods we examined 1) whether the mean orientation is represented in population-level orientation tuning responses in early visual areas as well as high-level fronto-parietal regions and 2) whether this tuning profile is modulated by the variance of orientation in sets of items. In the experiment, 30 small Gabor patches varying in orientation briefly appeared at random locations within a hypothetical circle and subjects were instructed to estimate their mean orientation and indicate it by a button press. Our behavioral data showed that the averaging performance was impaired as the orientation of Gabor patches became heterogeneous. We also found robust activation in parietal and dorsolateral prefrontal cortices while subjects performed the averaging task. Next, we estimated the tuning responses of the mean orientation in parietal and dorsolateral frontal cortices as well as early retinotopic visual areas. The results showed that the population-level orientation tuning functions peak at the mean orientation of sets of Gabor patches, and the tuning strength was attenuated as the variance in orientation increased, which reflects the decrease in behavioral performance. Our results suggest that early visual cortex and frontoparietal regions may serve to process ensemble coding, whereby summary statistics of visual stimuli are extracted.

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23.4084 Conjoint and independent representation of numerosity and area in human intraparietal cortex

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The posterior parietal cortex in primates has been implicated in representing different abstract quantities such as numerosity and spatial extent (e.g., object size). However, there is heated debate about the functional organization of the underlying representations. Recent evidence from single-unit recording in monkeys and population receptive field models in humans suggests that there are overlapping groups of parietal neurons tuned for both quantities. Here, using a continuous carry-over functional magnetic resonance imaging adaptation design, we asked whether the overlap in these representations reflects independent populations of neurons coding for each quantity separately, or a single neural population that is conjointly tuned to both quantities. Specifically, we presented images of dot arrays that varied concurrently in numerosity (2-5 dots) and cumulative area in a continuous, counterbalanced sequence. We modeled adaptation along these two dimensions with both a City-block and Euclidean contraction covariate. In the case of independent populations, neural adaptation will reflect the additive combinations of adaptation for number and area in isolation, as modeled by the City-block covariate. In the case of a single conjoint population, the amount of adaptation for a combined change will be subadditive, as modeled by the Euclidean contraction covariate. We found a subadditive amount of adaptation in a posterior region in the right intraparietal sulcus (rIPS), which overlaps with previously reported topographic maps for both dimensions. In contrast, we found an additive amount of adaptation in a more anterior region of the rIPS, as well as in both a posterior and anterior region in the left IPS (lIPS). Thus, we found evidence for both conjoint and independent populations of neurons, with neurons in the posterior rIPS conjointly representing numerosity and area, and neurons in the anterior regions of the rIPS and in the lIPS independently representing these dimensions.

Acknowledgement: This work was supported by a Scholar Award from the John Merck Fund to SFL, Emory College, Emory University (DD) and the National Science Foundation Graduate Research Fellowship Program under Grant No. DGE-1444932 (AP).

23.4085 Measuring Integration Processes in Visual Symmetry with Frequency-tagged EEG

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Previous brain imaging studies of symmetry have shown that several higher-tier visual areas have strong responses to mirror (Sasaki et al. 2005) and rotation symmetry (Kohler et al., 2016). The aim of the current work was to isolate dynamic signatures of brain responses associated with the integrative processes that underlie symmetry perception. We measured steady-state VEPs as participants viewed symmetric patterns comprised of distinct spatial regions presented a two different frequencies (f1/f2). Under these circumstances, the intermodulation (IM) components have been shown to capture integrative processing (Alp et al., 2016), because only neuronal populations that non-linearly integrate the parts of the image can produce these IMs. To measure integration processing during mirror symmetry perception, we used wallpaper patterns (Fedorov, 1891). For the mirror symmetric stimuli, we generated a PMM pattern containing two mirror symmetry axes by tiling the plane with a two-fold mirror symmetric lattice. We then diagonally split each lattice into separate parts to generate an image-pair that could be presented at different frequencies. To generate the control stimuli, we created a control pattern by rotating the first lattice by 90o, and then combining diagonally split images from the mismatched patterns. This procedure removes all mirror symmetry from the control image, while keeping local properties equal. All images contained translation and rotation symmetry, but mirror symmetry could only emerge through the combination of the image-pair in the mirror symmetric stimulus. Both mirror and control stimuli evoked activity at the IMs, indicating that non-linear integration is occurring for both pattern types. Several response components showed differential responses between the mirror and control stimuli, however, indicating symmetry-specific integration. There was a complex pattern of statistically reliable differences in both self-terms (2f1,2f2) and IMs (f2-f1), which suggests the involvement of distinctive non-linear global pooling in the presence of mirror symmetry.

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23.4086 Recurrent Interaction between Visual Cortical Areas Contributes to Contour Integration in the Human Brain: An fMRI-guided TMS Study

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One of the challenging task for the human visual system is how they extract and integrate the local elements from the cluttered background into the global contour perception. Although previous studies have suggested the involvement of both striate and extrastriate cortex for this intermediate-level processing of visual perception, their relative roles and dynamic interactions between these areas are largely unknown. To examine whether the recurrent processing between the lower and higher-level visual areas plays a causal role in contour integration, we applied fMRI-guided transcranial magnetic stimulation (TMS) on early visual cortex (V1/V2) and intermediate-level visual area (V3B) at four SOAs (60/80, 90/110, 120/140 or 150/170 ms) (plus a no-TMS condition) while the participants performed a contour detection task. Results showed that both V1/V2 and V3B were critically involved in the process of contour integration. Importantly, the first critical inference time window for V1/V2 (120/140 ms, $p < .05$, Cohen's $d = 0.57$) follows that for V3B (90/110 ms, $p < .05$, Cohen's $d = 0.58$). The inference effect was also found at 150/170 ms for both areas (V1/V2: $p = .05$, Cohen's $d = 0.50$; V3B: $p = .08$, Cohen's $d = 0.41$). These findings suggested that the critical contribution of V3B to contour integration was earlier than that of V1/V2. The present study provides direct evidence sup-

porting the causal role of the recurrent processing between V3B and V1/V2 in contour integration and agree with the data from monkey physiology. Our findings fit well with the incremental grouping theory (Roelfsema, 2006; Roelfsema & Houtkamp, 2011), in which a feedforward sweep generates a coarse template in higher visual areas with large receptive fields before the processing of detail information in lower visual areas with small receptive field through feedback mechanisms.

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23.4087 **Two-stage generative process in illusory shape perception: a MEG study**

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Grouping local parts into coherent shapes (e.g., illusory shape perception) is a central function in vision and has been suggested to be a generative process such that feedback signals carry predictions (i.e., the illusory shape) and feedforward signals represent prediction errors (i.e., the mismatch between predictions and actual bottom-up inputs). Although recent fMRI studies provide evidence supporting the predictive coding hypothesis in illusory shape perception, the neuronal dynamics and the associated brain regions underlying this generative process remains largely unknown. To address the issue, we recorded magnetoencephalography (MEG) signals while human subjects were presented with Pac-Man figures, the combination of which is either or not able to induce an illusory shape perception ('Kanizsa triangle'), corresponding to grouping and ungrouping conditions respectively. Critically, here we employed a temporal response function technique (TRF) combine with randomly modulated the luminance of each Pac-Man to extract neuronal response specific for each of the three Pac-Man figures. First, the TRF responses for grouping condition showed decreased activities compared to ungrouping condition, consistent with predictive coding account, given that the predictive errors are assumed to be smaller when shape perception is induced. Second, two time periods, one early and one late, associated with different neuronal oscillatory frequency and different brain regions, showed the inhibition effects. Specifically, within 100 ~150 ms, a beta-band (14-20 Hz) decrease was originated in bilateral early visual cortex (V1 and V2) and TPJ regions; within 200-400 ms, a theta-band (4-7 Hz) inhibition was found to arise from right IFG and TPJ regions. We propose that the illusory shape perception consists of two stages: an early one that quickly encodes predictive error in early sensory areas and a late one that performs background inhibition in right parietal and frontal regions after the establishment of illusory shape as foreground.

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23.4088 **The topographical relationship between visual field maps in association cortex and brain areas involved in non-visual cognition**

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Visual field maps have been found in all lobes of the brain. Multiple maps in association cortex are in or near regions associated with cognitive tasks that are not explicitly visual. Understanding the relationship between visually-defined areas and cognitively-defined areas will clarify our understanding of association cortex. Using fMRI, we investigated two pairs of visually defined and cognitively defined areas in individual subjects: (1) a visual field map in the inferior precentral sulcus (iPCS), and Broca's area, and (2) a visually responsive region in the temporoparietal junction (TPJ; Horiguchi et al., 2016, doi:10.1093/cercor/bhu226) and an area involved in theory of mind (ToM, Saxe & Kanwisher, 2003, doi:10.1016/S1053-8119(03)00230-1). Using an attention-demanding retinotopic mapping task (Mackey et al., 2016, doi:10.1101/083493), we defined visual field maps in iPCS and visually responsive regions in TPJ. In the same subjects, Broca's area was defined by a language localizer (words > jabberwocky sentences; Fedorenko et al.,2012, doi:10.1016/j.cub.2012.09.011), and a ToM area in TPJ from a story localizer (ToM stories > descriptions of pictures; Saxe & Kanwisher, 2003). We projected the contrast patterns onto the cortical surface and compared their locations to the previously defined visual areas. We found that Broca's area was left-lateralized, on or near the pars opercularis and/or par triangularis, and just anterior to, but not overlapping (< 2% overlap), iPCS maps. Second, we found that ToM activation patterns in the TPJ were more posterior and superior, closer to the angular gyrus, compared to the visually defined TPJ region, which was closer to the planum temporale, again with no overlap. The individual subject analysis shows that the positions of the visual areas in association cortex are systematically related to, but not overlapping with, regions defined by cognitive tasks.

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23.4089 **Top-down neural processing that supplements missing image features revealed by brain decoding with deep neural network representation**

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The problem of visual recognition entails matching the sensory input with the stored knowledge of semantic information. This process involves a feed-forward component where visual input is processed to extract features characterizing different objects. It is also presumed to involve an opposite processing pathway where high-level features propagate back providing prediction on the kind of visual stimulus presented. This top-down pathway appears to be useful particularly for tasks like processing degraded stimuli. The process by which the forward and backward pathways integrate leading to visual perception is still largely unknown. Here, using a deep neural network (DNN) trained to recognize objects as a proxy for hierarchical neural representations (Horikawa & Kamitani, 2015), we demonstrate that top-down processing pathway attempts to supplement missing visual features. We first trained multivoxel fMRI decoders to predict DNN features of multiple layers for stimulus images. The trained decoders were then used to analyze independent fMRI data collected while viewing pairs of normal and degraded images. Degraded images were created by blurring original images using averaging filters, and by binarizing slightly blurred images using thresholding. We found that decoded features from fMRI responses to degraded images were more correlated to DNN features calculated from the original images than from the degraded (presented) ones. This was especially salient in the lower level DNN representations. We also found that the task of categorizing the visual stimuli increased the correlation difference especially in higher visual areas. These results suggest the operation of the top-down pathway as it attempts to supplement the missing information in degraded images. The effect of the categorizing task may indicate how giving a prior guides the exploration efforts towards successful perception. This DNN-based brain decoding approach may reveal the interactions between the bottom-up and the top-down pathways, providing empirical evidence for existing and novel theoretical models.

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23.4090 **Visual hallucinations following occipital stroke associated with altered structural connectivity**

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Irreversible damage to the visual pathway that results in vision loss can produce visual hallucinations in cognitively healthy individuals. These visual hallucinations stem from disruption to neuronal function that leads to aberrant functional activity across visual cortices and associated cortical networks. We sought to investigate structural changes in white matter connectivity and its contribution to chronic visual hallucinations following damage to the visual cortex. We performed diffusion tensor imaging to assess white matter in a patient suffering from continuous and disruptive unformed visual hallucinations for more than 2 years following right occipital stroke, and in healthy age-matched controls. White matter structure was reconstructed using probabilistic fibre tractography, and diffusion was quantified by measuring diffusion tensor indices. Using probabilistic tractography, we reconstructed reciprocal white matter tracts between the lateral geniculate nucleus and visual cortex, and between visual cortices.

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Tracts were further reconstructed from visual cortex to frontal, temporal, and parietal regions of interest based on fMRI findings showing functional differences in the patient compared with healthy age-matched controls. White matter tracts showed regeneration of terminal fibres of ipsilesional optic radiations in the patient that were displaced anterior to the lesion site; however, reciprocal intrahemispheric tracts from ipsilesional visual cortex to lateral geniculate body were disrupted. There was an absence of interhemispheric white matter tracts from ipsilesional to contralesional primary visual cortex, while contralesional to ipsilesional tracts were spared in the patient. Further, we observed compromised structural characteristics and changes in diffusion of white matter tracts in the patient connecting the visual cortex with frontal and temporal regions. This cortical remapping and disruption of communication between visual cortices and from visual cortex to remote regions is consistent with our previous findings showing imbalanced functional activity of the same regions associated with chronic visual hallucinations in the patient.

Temporal Processing: Duration

Saturday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4091 Individual differences in the perception of (a bigger) time

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The ability of subjects to identify and reproduce brief temporal intervals is influenced by many factors whether stimulus-, task- or subject-based. Previously we have shown the effects of personality on sub-second timing judgements (VSS 2015); the current study extends this result to supra-second judgements, to examine the postulated dissociation between sub- and supra-second timing mechanisms. 141 undergraduate subjects completed the OLIFE schizotypal personality questionnaire prior to performing a modified temporal-bisection task. Subjects responded to two identical instantiations of a 4deg grating, presented 4deg above fixation for 3 secs in a rectangular temporal-envelope. They initiated presentation with a button-press, and released the button when they considered the stimulus to be half-way through. Subjects were then asked to indicate their 'most accurate estimate' of the two intervals. The stimuli were static and blocked into four repeats of 50 stimulus pairs. The significant order-effect seen in the sub-second data disappeared; this was at the expense of accuracy, as the mid-point was consistently underestimated. Precision in the response was increased as a proportion of total duration, reducing the variance below that predicted by Weber's law. This result is consistent with a breakdown of the scalar properties of time perception in the early supra-second range. All subjects showed good insight into their own performance, though that insight did not necessarily correlate with the veridical bisection point; they were consistently and confidently wrong. The significant correlations with schizotypy seen in the sub-second data were not replicated in the current study. These data support a partial dissociation of timing mechanisms, but also suggest that not only is perception the critical mitigator of confidence in time, but that individuals effectively compensate for differences in perception at the level of metacognition in early supra-second time.

23.4092 Perception of duration in the absence of the clock reset

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Models of time perception propose different mechanisms, varying in complexity and levels of explanation (Block & Grondin, 2014; Matthews & Meck, 2014). However, most models assume that in order to estimate duration a clear onset of to-be-time interval is needed. We aimed to explore this assumption by investigating estimation of time in absence of the onset of the interval. Stimuli consisted of a small disc rotating around a clock with variable speeds. After a variable duration, the disc would stop and participants were prompted to reproduce the duration of the last rotation. Since the stopping position was random, there was no salient onset of the last rotation. In order to investigate the contribution of visual information on the timings, we introduced an occlusion along the path of the disc. We compared performance in non-occluded and occluded conditions. In addition, there were conditions in which the disc could abruptly change speed behind the occluder, to investigate the effect of unexpected event on perceived duration. In agreement with previous work, short durations (stimuli moving fast) are perceived to last longer while long durations are underestimated (Jazayeri & Shadlen, 2010). Moreover, bias and variability of reproduced durations in this task were comparable to a control experiment with clear onset of the duration. Importantly and surprisingly, reproduced times were less biased in the occluded condition. Past work has revealed that perceived duration is biased by visual information (Kaneko & Murakami, 2009). Our results indicate that when visual information is not always available, participants properly take into account the duration during which stimulus is absent and their overall performance is improved. Taken together, our results suggest that timing is possible without assuming any reset of a clock. We propose ways to modify existing models of time perception to account for our results.

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23.4093 Stimulus response compatibility affects duration judgments, not the rate of an internal timer.

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Varakin, Hays, and Renfro (2015, VSS) demonstrated that stimulus response compatibility (SRC) influences duration judgments. The current experiment tested whether SRC affects an internal timer's rate. Participants (N = 215) performed a temporal bisection task, judging on each trial whether a visual stimulus' duration was closer to pre-learned short or long standards. Response mapping was counterbalanced: about half of participants used a right-hand key for "long" judgments and a left-hand key for "short" judgments, vice versa for remaining participants. On each trial, stimuli appeared on the left or right side of the monitor, thus inducing SRC. Two additional factors were manipulated. The first was the temporal location of the SRC-relevant stimulus. In the "during" condition, the stimulus being judged appeared on the left or the right of fixation. In the "after" condition, the stimulus being judged appeared in the center of the monitor, and the response prompt appeared on the left or right of fixation. If SRC only changes the rate of an internal timer, then SRC might not be observed in the "after" condition, because the relevant temporal interval had ended when SRC was introduced. The third factor was the magnitude of short/long standard durations, which were either 200ms/800ms or 400ms/1600ms. If SRC changes the rate of an internal timer, the SRC effect should be smaller for 200ms/800ms standards than for 400ms/1600ms. The results replicated SRC's influence on temporal bisection: long-compatible stimuli reliably elicited long judgments at shorter durations than short-compatible stimuli. However, SRC was observed even when it was present only after the relevant temporal interval ended, and SRC did not interact with the magnitude of the short and long standards. Overall, these results suggest that SRC did not affect the rate of an internal timer, but may have affected processes otherwise unrelated to time perception.

23.4094 Central tendency effects override and generalize across illusions in time estimation

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Illusions and central tendency effects strongly modulate temporal interval estimations. First, interval estimations are subject to distortions during active and passive observation: Interval compression occurs when an action produces a stimulus or when one of the interval markers is masked. Second, central tendency effects consist in an overestimation of short and an underestimation of long intervals. To understand the functional role of both phenomena, I asked which effect would dominate if both are set into direct competition. To this end, I tested two temporal illusions: active intentional compression and passive mask-induced compression. Both illusions produced systematic underestimations when several intervals durations were presented in blockwise fashion. However, strong central tendency effects occurred when interval duration was randomized. I presented an interval of 112 ms intermixed either in a context of 5 shorter (32-96 ms) or 5 longer (128-192 ms) intervals. The 112 ms interval compressed to about half of its duration when presented only with shorter intervals and dilated by a factor of 1.5 when presented only with shorter intervals. Central tendency effects thus clearly dominated interval estimations. Next, I asked about the generality of central tendency effects by testing their transfer between the illusions. I presented the active illusion with a duration of 112 ms either with 5 shorter or with 5 longer passive illusion intervals. In separate sessions, I presented the passive illusion for 112 ms intermixed into either shorter or longer active illusion intervals. Central tendency effects induced in either the active or the passive illusion intervals transferred to the other illusion. These results demonstrate that the immediate context of sensory stimulation determines whether intervals appear compressed or dilates, irrespective of whether the interval is actively produced or passively observed. This is consistent with recent bayesian explanations of time estimation.

23.4095 **Synchronized stimuli are perceived to be shorter** Bo-Rong Lin[1](linbr@psych.ac.cn), Chang-Bing Huang[1]; [1]Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences University of Chinese Academy of Sciences, CAS Visual Information Processing Laboratory (VisPal), Institute of Psychology, CAS

Processing and telling time, or time perception, is vital for the survival of any organism. A variety of spatial cues have been found to be effective in modulating observers' time perception. Here, we investigated the effect of synchronization, a form of temporal cue, on the perceived duration of visual stimuli in which spatial cues were largely controlled. Stimuli were 100 non-overlapping Gabor patches moving in one of two directions that orthogonal to their orientations. Synchronization of Gabor patches were defined by entropy and correlation; entropy refers to the probability of moving direction change and correlation refers to the likelihood that all Gabor elements reverse their motion directions simultaneously. In Experiment 1, nineteen observers performed a duration discrimination task that included four pairs of stimuli that differed in entropy and correlation and found that stimuli with high synchronization were perceived significantly shorter (by ~50ms) than random but otherwise identical stimuli of the same duration. This contraction effect couldn't be explained by change in perceived speed (Experiment 2). Varying the display duration from 350 to 1050ms didn't significantly affect the magnitude of perceived contraction (Experiment 3). Furthermore, we found no significant difference in both appearance and disappearance detection times to stimuli (Experiment 4), ruling out the possibility of different detection time with stimuli of different synchronization factors. Taken together, our findings suggest that synchronization can also effectively modulate time perception, possibly acting via slowing down the pacemaker, an essential part of the internal clock.

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23.4096 **A superposition of moving and static stimuli appears to dilate in time when the moving stimulus is attended to** Daisuke Hayashi[1](daisuke@fechner.c.u-tokyo.ac.jp), Hiroki Iwasawa[1], Takayuki Osugi[2], Ikuya Murakami[1]; [1]Department of Psychology, The University of Tokyo, [2]Department of Human Sciences and Cultural Studies, Yamagata University

A moving stimulus appears to last longer than a static one. This time dilation in a moving stimulus has been explained by stimulus domains, such as temporal frequency and speed (e. g. Kanai et al., 2006; Kaneko & Murakami, 2009). However, previous studies have presented moving and static stimuli separately, and it is still unknown whether the observer's attentional set to the moving stimulus affects perceived duration when the moving and static stimuli overlap in the same location. We presented moving and static random-dot patterns simultaneously within the same field and instructed the observer to attend to either one of these patterns colored differently. We measured the perceived duration of the attended pattern in the two-interval forced-choice paradigm with the method of constant stimuli. The standard stimulus consisted of 300 moving dots and 300 static dots whereas the comparison stimulus consisted of 300 static dots. The standard stimulus appeared to last longer when the moving stimulus was attended to than when the static one was attended to, even though the physical display was the same between conditions. Subsidiary experiments demonstrated that the difference in perceived duration between the attend-to-moving and attend-to-static conditions increased proportionally to the physical duration and that, compared to the apparent duration of a static pattern alone, attending to the static pattern in the superposition did not last shorter when it was added to the moving pattern that had already appeared for one second. These results indicate that endogenous attention to a moving stimulus is a crucial component of the time dilation and that a simultaneously appearing stimulus within the superposition can draw exogenous attention, affecting the perceived duration. In the pacemaker-accumulator framework, these effects can be explained by selective accumulation of temporal units by feature-based attention.

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23.4097 **Time compression, but not dilation, in slowly moving stimuli** Saya Kashiwakura[1], Isamu Motoyoshi[2]; [1]Department of Integrated Sciences, The University of Tokyo, [2]Department of Life Sciences, The University of Tokyo

A number of psychophysical studies have shown that a moving visual stimulus is perceived to last longer than a stationary stimulus. In contrast, here we report a case in which the perceived duration of a moving stimulus is shorter than that of a stationary stimulus. In our procedure, observers viewed a natural movie (i.e., a running horse) that was presented at a particular speed (0.0, 0.25, or 1.9 relative to the original speed) for a particular duration (0.5, 1.1, or 1.6 sec), and indicated whether its duration appeared longer or shorter than that of the comparison movie presented at the original speed. We found that the duration of the movie with a slow speed (i.e., 0.25 speed) was perceived to be shorter than that of a static image (i.e., 0.0 speed), especially when the physical duration of the stimulus was longer than 1.1 sec. The perceived duration of a fast movie was longer than that of a static image as consistent with previous studies. Similar patterns of the results were obtained when we employed artificial stimuli such as drifting gratings, and when we measured the perceived duration by manual reproduction. These results are inconsistent with the fundamental assumption of time perception that the subjective experience of time passage depends on the number of changes or events. We discuss potential factors that may account for this paradoxical effect.

Acknowledgement: This study was partially supported by JSPS KAKENHI JP16H01499 and JP15H03461.

23.4098 **Task-relevant attention and repetition suppression co-determine perceived duration** Yong-Jun Lin[1](mentist@gmail.com), Shinsuke Shimojo[1]; [1]Computation and Neural Systems, California Institute of Technology

Duration perception of an event can be influenced by the temporal context. One such phenomenon is subjective time expansion induced in an oddball paradigm ("oddball chronostasis"), where the duration of a novel item (oddball) appears longer than that of repeated items (standards). Two leading theories are 1) attention enhances oddball duration [Tse et al., 2004] and 2) repetition suppression reduces standards duration [Pariyadath & Eagleman, 2007]. However, no studies so far have evaluated both together. We thus measured observers' chronostasis magnitude (CM) with constant stimuli method, where CM = standard duration - point of subjective equality of the target, and manipulated three sequences types: repeated, ordered and random (Fig 1a). The stimuli dimensions were digits, orientations, and colors in Exp 1, 2, and 3, respectively (Fig 1b-d). The repeated condition was the classic oddball paradigm. In the ordered condition, items never repeated; the target was the item that did not follow the order. In the random condition, the observers were instructed which item would be the target while the other items were random and unpredictable. Positive CM in the random condition would indicate task-relevant attention effect. From random to ordered condition, CM increment would imply prediction error effect; from ordered to repeated condition, it would imply repetition suppression. Results in Exp 1 and 2 revealed task-relevant attention and repetition suppression effects (Fig 2a,b); results in Exp 3 showed only task-relevant attention effect (Fig 2c). In Exp 1 and 2, attention and repetition suppression contributed about equally. In all experiments, CM correlations between sequence type condition pairs were mostly significant (Tab 1), indicating a common factor, which is likely task-relevant attention. Hence, both attention and repetition suppression are necessary for explaining the original oddball phenomenon. In the special case of colors, attention alone may be sufficient as an account.

Acknowledgement: NSF-1439372 and JST.CREST to Shinsuke Shimojo

23.4099 **Attention mediates the encoding of duration** Jim Maarseveen[1](J.Maarseveen@uu.nl), Hinze Hogendoorn[1], Frans Verstraten[1,2], Chris Paffen[1]; [1]Utrecht University, Helmholtz Institute, Department of Experimental Psychology, The Netherlands , [2]University of Sydney, Faculty of Science, School of Psychology, Sydney, NSW 2006, Australia

Attention has been suggested to play an important role in duration processing. Here, we investigated whether attention mediates the encoding of the durations of multiple events by measuring the duration after-effect (DAE) following adaptation to concurrently presented events with different durations. Observers adapted by viewing two streams of Gaussian blobs displayed to the left and right of a central fixation cross. In Experiment 1, blobs in one stream lasted 200 ms while the blobs in the other stream lasted 800 ms. To manipulate attention, observers were instructed to perform a duration-oddball detection task on one of the streams (and ignore the other), while maintaining central fixation. In Experiment 2, observers adapted in three conditions: repetitions of blobs lasting 200 and 400 ms, while performing the oddball task on the 200 ms blobs (Attended: 200 ms, Unattended: 400 ms; A200/U400) or the 400 ms blobs (A400/U200), or to repetitions of blobs that both lasted 400 ms, while performing the oddball task on one of the streams (A400/U400). To measure the DAE, observers completed a cross-modal duration judgment task in which they compared a fixed auditory reference to a visual test stimulus with a varying duration. The results of Experiment 1 reveal that attending to blobs lasting 200 ms caused an after-effect in line with adaptation to 200 ms, while attending 800 ms blobs caused an after-effect in line with adaptation to 800 ms. This shows that the magnitude of the DAE depended on which duration was attended to during adaptation. Experiment 2 revealed no difference between the after-effects when the unattended stimulus lasted 200 ms (A400/U200) and when it lasted 400 ms (A400/U400), demonstrating that the unattended duration does not contribute to the measured DAE. These results show that attention plays a crucial role in selecting which durations are encoded.

23.4100 **Luminance motion induces larger time compression and larger time dilation than equiluminant motion** Hiroshi Yoshimatsu[1](yoshimatsu@fechner.c.u-tokyo.ac.jp), Yuki Murai[1,2], Yuko Yotsumoto[1]; [1]Department of Life Sciences, The University of Tokyo, [2]Japan Society for the Promotion of Science

After adapting to a moving stimulus, the duration of another moving stimulus presented at the adapted location is underestimated (adaptation-induced time compression). On the other hand, the duration of moving stimulus is overestimated than that of static stimulus (time dilation). The compression effect has been reported to be selective to luminance motion and then considered to relate to early motion processing such as the magnocellular pathway. In contrast, the dilation effect has been considered to relate to higher motion processing such as the area MT, however, the luminance selectivity of this effect remains unknown. In this study, we directly compared the adaptation-induced time compression and the time dilation, in terms of luminance selectivity. In the experiments, we measured the time compression and the time dilation for luminance gratings and subjectively equiluminant color gratings (0.5 cpd, diam 8°). In the experiment of time dilation, observers compared the duration of a moving (7 Hz) standard stimulus and that of a static test. In the experiment of time compression, the adaptor was presented at the beginning of each trial, and observers compared the durations of two moving (7 Hz) stimuli: standard presented at the adapted location and test at another location. All stimuli were centered at 5° eccentricity. The standard duration was 600 ms and the test duration was variable (300-1200 ms). We found that the luminance motion induced significantly larger time compressions (~17%) than the equiluminance motion (~7%), consistent with the previous studies. Furthermore, significant time dilations were observed for the luminance motion (~22%), but not for the equiluminant motion. These results indicate the luminance motion induces larger motion-induced time distortions. Our study suggests that the early visual processing such as the magnocellular pathway is responsible for both the time compression and the time dilation.

23.4101 **Temporal windows in psychophysical discrimination and in neural responses in human visual cortex** Jingyang Zhou[1](jyz205@nyu.edu), Silvia Choi[1], Jonathan Winawer[1]; [1]Department of Psychology, New York University

Previously at VSS (Zhou et al., 2016, 56.4040), we presented a model of temporal responses to briefly viewed stimuli measured with fMRI and intracranial electrodes. We showed that the duration over which responses to visual stimuli interact, a temporal window, increases along the visual hierarchy. Here, we tested a behavioral correlate of the different temporal window lengths with several psychophysical tasks designed such that performance was expected to be limited by different stages of cortical processing. We adopted a psychophysics paradigm similar to Burr and Santoro 2001, (doi:10.1016/S0042-6989(01)00072-4), in which we measured discrimination sensitivity as a function of exposure duration, defining the temporal window for a given task as the duration at which sensitivity saturated (the inflection point in the sensitivity versus duration plots). The first two tasks were adapted from Burr and Santoro, and the third was novel: (1) contrast thresholds for dot motion direction judgments (left or right; 100% coherence); (2) coherence thresholds for dot motion direction judgments (left or right; high contrast); (3) contrast thresholds for judgments of facial emotional expression (happy or sad). Task 1 was expected to isolate a first stage motion mechanism that is spatially local, represented in early visual areas (V1), with short temporal windows. Task 2 was expected to be limited by a second stage motion mechanism which integrates motion direction over large regions (MT or MST), with longer temporal windows. Task 3 was expected to be limited by a late stage object recognition mechanism, with long temporal windows. The results were in accord with these predictions, with short temporal windows for Task 1 (~300 ms) and long windows for Tasks 2 and 3 (~1000 ms; ~1700 ms). Future work will test explicit linking models that predict the psychophysical window length from the neural models.

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Multisensory: Vision and audition

Saturday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4102 **Oculomotor Response Precedes Awareness Access of Multisensory Emotional Information Under Interocular Suppression** Yung-Hao Yang[1](yunghaoyang@gmail.com), Su-Ling Yeh[1]; [1]Department of Psychology National Taiwan University, Taiwan

Previous studies have shown that emotional salient information can attract attention in the absence of visual awareness. Since affective voice can enhance emotional meaning of facial expression, we tested whether emotional congruency of affective voices can also modulate attention allocation of invisible facial expressions. We adopted the continuous flash suppression (CFS) paradigm to render facial expressions (e.g., happy and fearful) invisible to the participants, and manipulated affective voices (e.g., laughing and screaming) to generate either congruent or incongruent condition. We measured the time releasing from interocular suppression and simultaneously recorded eye movement as an index of attention allocation. The results showed that happy faces have shorter first saccade latency and shorter suppression time than fearful face, the latter result had been replicated by experiments with different data bases. Importantly, congruent affective voices revealed shorter dwell time and shorter suppression time than incongruent counterparts. The results suggest that affective voice can influence the attention attraction of invisible facial expression. In addition, these results also provide new evidence that emotional meaning of facial expression can be extracted under interocular suppression and thus integrated with affective voice. Keywords: Facial expression, multisensory integration, unconscious processing, eye-movement

Acknowledgement: This research was supported by Taiwan's Ministry of Science and Technology under Grant 104-2420-H-002 -003 -MY2 to Dr. Su-Ling Yeh

23.4103 **Context dependent crossmodal assocations between visual spatial frequencies and auditory amplitude modulation rates.** Joo Huang TAN[1](jootan@u.duke.nus.edu), Po-Jang HSIEH[1]; [1]Duke-NUS Medical School

Our percept of the world is a multisensory one. In order to successfully navigate our surrounds, we must integrate information originating from different modalities. Here, we delve into the relationship between two low level sensory features. Specifically, we investigated the highly specific perceptual matches that exist between auditory amplitude modulation (AM) rate and visual spatial frequency. We conducted a series of perceptual matching tasks between visual spatial frequencies and auditory AM rates. Participants were tasked to adjust the AM rates of the sound stimulus to match the spatial frequency of a grating stimulus displayed on screen. Each participant was only presented with one specific visual spatial frequency for the experiment. Initial AM rate of the sound stimulus at the start of each trial was manipulated as an independent variable across subjects. We demonstrate that perceptual associations made between specific pairs of visual spatial frequencies and auditory amplitude modulation rates are highly conserved across individuals within specific experimental context. However, these associations are highly, and easily influenced by auditory context. This work serves to demonstrate the point that sensory context can exert strong influences on crossmodal associations.

23.4104 Look at me when I'm talking to you! Sound influences gaze behaviour in a 'split-screen' film

Jonathan Batten[1](jonobatten@gmail.com), Jennifer Haensel[1], Tim Smith[1]; [1]Psychological Sciences, Birkbeck, University of London

Viewing a dynamic audiovisual scene has inherent challenges for where and when gaze is allocated because of the competing and transient sensory information. The applied craft of film production has developed intuitive solutions for guiding viewers' gaze through visual and sound editing techniques, for example sound designers believe that increasing the loudness of dialogue relative to background ambient noise orients a viewers' attention to the speaking character. A fundamental assumption of these techniques is that a viewer's gaze is attracted to audiovisual elements in a scene and inversely less attracted to visual events without sound. Empirical evidence of viewing behaviour to dynamic scenes has predominantly focused on visual features, the role of sound as an influence on viewers' gaze is less clear. This study utilised a found experiment, Mike Figgis's experimental feature film, Timecode (2000) which contains four continuous perspectives of interrelated events displayed using a 2x2 split-screen, where each quadrant has an isolatable sound mix. We investigated the influence of sound on gaze behaviour to a 4 minute 50 second excerpt by manipulating the presence of sound across the four quadrants one at a time with abrupt sound cuts shifting sound 16 times (each quadrant represented four times). Forty-eight participants free-viewed the clip whilst being eye-tracked (sound order was counterbalanced across participants). Sound representation to a quadrant significantly increased the proportion of gaze to that region. Gaze was also influenced by time, as later sound representations of a quadrant had a significantly higher proportion of gaze than earlier ones. Fixation durations to sound regions were significantly longer than those to visual only quadrants. The auditory and visual salience values are also considered as predictors of gaze between the quadrants. These preliminary results suggest that dynamic scene viewing behaviour is significantly influenced by the inclusion of corresponding sound.

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23.4106 Limits of sensory fusion in audio-visual cue conflict stimuli

Baptiste Caziot[1,2](baptiste.caziot@ens.fr), Pascal Mamassian[1,2]; [1]Ecole Normale Supérieure, [2]Paris Sciences et Lettres

What are the limits of sensory fusion in cue conflict stimuli? We recorded perceptual reports and RTs for discrepant audio and visual cues. A shape subtending approximately 10 deg was displayed twice during 83 ms separated by 333 ms on a monitor. The size of the shape changed between the two occurrences so as to simulate a displacement in depth. Simultaneous with the visual displays, auditory white noise was played through headphones with varying loudness also simulating a distance change (inverse square law). Participants reported whether the target was approaching or receding. We recorded unimodal and bimodal performance. In bimodal trials the 2 cues were either congruent (simulating the same change in depth), or opposite creating a strong conflict between cues. From block to block observers were instructed to report the direction of either the visual signal or the auditory signal. We found that in visual blocks perceptual reports were similar in the unimodal, congruent and conflict conditions, as were response times. Thus responses appear to have been mediated by the visual signal alone. In sharp contrast, in auditory blocks perceptual decisions were more precise in the congruent condition than the unimodal condition. But perceptual decisions were very poor in the conflict condition, and response times were longer. Therefore observers could disregard the auditory signal when paying attention to the visual signal, but were unable to suppress the visual signal when paying attention to the auditory signal. In a separate experiment observers were unaware of the cue conflict and fused the cues optimally. A mixture model (Knill, 2003; Körding et al., 2007), where the probability to fuse the cues decrease with increasing conflict captured the pattern of results only if different fusion functions are used in the different tasks, underlying the strong contribution of task in sensory fusion.

Acknowledgement: NSF/ANR - CRCNS 1430262

23.4107 The Expanding and Shrinking Double Flash: An Auditory Triggered Dynamic Replay of a Visual Stimulus

Noelle Stiles[1,2](n-stiles@caltech.edu), Armand Tanguay, Jr.[1,3], Shinsuke Shimojo[1]; [1]Division of Biology and Biological Engineering, California Institute of Technology, [2]Department of Ophthalmology, University of Southern California, [3]Departments of Electrical Engineering, Biomedical Engineering, and Ophthalmology, University of Southern California

Background: In the double flash illusion, a visual flash can be doubled by the presentation of two beeps, one simultaneously with the flash and one following (Shams, et al., 2000). The current study found that a visual flash of a static spatial gradient (black at the center to white at the edges on a white background), can generate the perception of visual expansion then contraction. Furthermore, when multiple beeps are played during and after the visual gradient flash, the visual expansion then contraction is perceived twice. Methods: A single flash of either a black circle with sharp edges (SE) or a circular gradient (G) is presented for 20 ms. One, two, or three beeps of 6 ms each are paired with this flash, randomly across trials. Participants (N = 7) were asked to report the number of flashes perceived and the type of perception (e.g., for 1 flash: a circle expanding then shrinking, a circle shrinking then expanding, or a flash of constant size). Results: Participants reported significantly more flashes for the two and three beep conditions compared to the single beep condition for both the SE and G flashes ($p < 0.005$). Participants indicated significantly more dynamics (expansion or shrinking) for the G flash as compared to the SE flash ($p < 0.005$). Participants also verbally indicated that the illusory flash for the G stimulus (i.e., the second flash when two flashes were reported) had the same dynamic visual expansion as the real first flash. Discussion: The double flash illusion occurs even with a gradient stimulus. We hypothesize that the gradient flash generates a perception of expansion due to higher contrast regions being processed faster (Seiffert and Cavanagh, 1999). As the center region has the highest instantaneous contrast, it is processed faster than the rest of the gradient.

23.4108 The Spatial Double Flash Illusion: Audition-Induced Spatial Displacement

Armand Tanguay, Jr.[1,2](atanguay@usc.edu), Bolton Bailey[2], Noelle Stiles[2,3], Carmel Levitan[2,4], Shinsuke Shimojo[2]; [1]Departments of Electrical Engineering, Biomedical Engineering, and Ophthalmology, University of Southern California, [2]Division of Biology and Biological Engineering, California Institute of Technology, [3]Department of Ophthalmology, University of Southern California, [4]Department of Cognitive Science, Occidental College

Background: The spatial double flash illusion is generated by the brief presentation of a central visual stimulus (a small rectangular target; a "flash") in conjunction with a short auditory stimulus (a "beep") that is physically displaced to the left (or right) of the central (peripheral) flash, followed by a second identical auditory stimulus that is physically displaced to the right (or left) of the single flash. The second beep generates an illusory flash that is displaced in the direction of the auditory beep sequence. This illusion is a variant of the original double flash illusion with no audio displacement (Shams, et al., 2000). Methods: A 17 ms flash of a white rectangle against a grey background is presented centrally, displaced by 11.5° vertically below a fixation cross, in conjunction with a 7 ms 800 Hz audio tone (beep). A second beep is generated 57 ms following the first beep. The two speakers used to present the beeps are displaced to the left and right of a centrally located monitor. Participants (N = 10) were asked to report the number of flashes perceived, whether or not the two flashes were collocated or displaced, and if displaced, in which direction. Results: Participants reported significantly more illusory flashes displaced in the direction of the auditory beep sequence than in the opposite direction (Left to right, $p = 0.011$; Right to left, $p = 0.036$). Discussion: The illusory flash following the presented flash was perceived to be displaced laterally in space in the same direction as the sequence of audio stimuli predominantly more often than it was per-

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ceived to be displaced in the opposite direction. As such, both the generation of the illusory flash and its location are modified by auditory input, an unusual example of crossmodal interaction in which audition dominates over vision.

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23.4109 **Protective effects of combined audiovisual stimulation on temporal expectations in noisy environments** Felix Ball[1,2](FelixBall@gmx.de), Lara Michels[1], Fabienne Fuehrmann[1], Johanna Starke[1,2], Toemme Noesselt[1,3]; [1]Department of Biological Psychology, Otto-von-Guericke University, Magdeburg, Germany, [2]Department of Neurology, Otto-von-Guericke University, Magdeburg, Germany, [3]Center of Behavioural Brain Sciences, Otto-von-Guericke University, Magdeburg, Germany

In real life, we are exposed to a rich environment, a complex and continuous stream of multisensory information. This information needs to be integrated to generate a reliable mental model of our world. There is converging evidence that there are at least two optimization mechanisms to integrate incoming information: multisensory interactions (MSI) and temporal expectations (TE). However, how these mechanisms interact is currently unknown. In a series of 4 psychophysical experiments we tested whether MSI-induced behavioral benefits interact with TE-induced benefits, and whether these effects are affected by distinct experimental contexts. In particular, auditory (A) and/or visual (V) stimulus sequences were presented either alone or simultaneously in all experiments. Participants discriminated visual and/or auditory frequencies of deviant target stimuli (high/low) within each sequence. Moreover, temporal expectation about time-of-target-occurrence was manipulated block-wise: targets preferentially occurred either early ('early block') or late ('late block') within the stimulus sequence within each block. Task difficulty was further altered by using speakers ('same location', Exp. 1 & 3) or headphones ('different location', Exp. 2 & 4), and by changing the predictability of target modality (predictable: Exp.1 & 2, unpredictable: Exp. 3 & 4). Multisensory interplay was always quantified by comparing subject-specific performance during multisensory stimulation with performance in the best unisensory condition (max-criterion). We observed distinct effects for MSI: multisensory enhancement was dependent on task difficulty, increased with increasing noise and was dominant when participants reported having problems with the task. Remarkably, TE effects were also enhanced for multisensory relative to unisensory stimulation and TE effects for unisensory stimuli even vanished under high spatial uncertainty. Together, the pattern of results indicate that multisensory stimulation has a protective and enhancing effect on the generation and usage of temporal expectations, highlighting the need for multisensory paradigms in future studies investigating temporal expectations.

Acknowledgement: SFB-TR31-TPA08

23.4110 **Processing of congruent and incongruent facial expressions during listening to music: an eye-tracking study** Kari Kallinen[1](kari.kallinen@mil.fi); [1]Finnish Defense Research Agency

Introduction Studies have shown that (a) multimodal emotional experience might be increased in the combined music-picture condition and (b) that music influences ratings on visual stimuli. However, there is scarcityof studies that examine the potential moderating effects of music on looking at images. In the present paper we report the results of an eye-tracking study on congruent and incongruent emotional music (joy, sad, and anger) and facial expressions (happy and sad). We expected that facial expressions congruent to music would attach more attention than incongruent faces. In addition, we expected that angry music (which had no corresponding face images), would elicit higest eye-movement activity between the facial expression (as the subject search for corresponding facial expression). Methods Five men and five women aged 33-64 years (M=46,9) took part in the experiment. Their task was to listen to three pieces of music (a priori sad, joyful and angry) and at the same time look at facial expressions (sad and happy) presented in the screen. Eye movements were tracked with Ergoneer Dikablis eye-tracker during listening to music and watching the facial expressions. Results As expected, in connection joyful and sad music the congruent faces (i.e., happy faces for joyful music and sad faces for sad music) elicited more attention in terms of AOI attention ratio and total glance time as compared for incongruent faces (for AOI attention ratio Ms = 53,2% and 36,7%; p=.002; for total glance time Ms =12,9 and 8,88 seconds, p=.002) . In connection with music that expressed anger the preliminary analysis showed no effects. Conclusion The results give new information about the interactive effects of emotional music and facial expressions. The knowledge about the effects of music on image processing and interaction between music and images are important and useful, among other things, in the context of (multi)media design and presentation.

23.4111 **Cross-modal Matching as a Means of Stimulus Norming for the Visual World Paradigm** Kelly Dickerson[1](kdicker1@binghamton.edu), Brandon Perelman[1], Peter Gerhardstein[2]; [1]Human Research and Engineering Directorate, US Army Research Laboratory, [2]Department of Psychology, Binghamton University

The visual world paradigm (VWP) has been used to evaluate how a variety of cognitive and contextual factors influence the deployment of visual spatial attention. Previous VWP studies have employed linguistic cues, where a spoken or written target word immediately precedes a search array. This method of cuing is effective and easily controlled but lacks ecological validity. A more ecologically valid way to cue a visual event would be to use environmental sounds as cues. While this answer to ecological validity seems straightforward, matching audio and visual cues when those cues are meant to represent real objects is methodologically challenging. The present study attempts to meet this challenge by using subjective ratings of stimulus attributes as our matching variables. This study contains 150 stimuli (50 images, 100 sounds) that were rated by 10 participants for pleasantness and familiarity. For each stimulus participants were also asked for an open-ended identification response. Following the subjective ratings phase of the experiment participants completed a 4AFC task where each of the 50 images was presented with two matched (target) sounds and two mismatched (lures) sounds. There were no significant differences between sounds and images for pleasantness or familiarity. There was a significant difference in identification accuracy between sounds and images, with images being slightly more accurately identified than sounds. In the 4AFC task participants were highly accurate at selecting one of the two matched sounds, and false alarms (responses to lures) were generally low. When a matched auditory stimulus was selected the participant was significantly more likely to select the more pleasant or familiar of the two sounds. These results will inform stimulus selection and matching in a future VWP study. Using subjective factors for cross-modal matching is one possible approach to overcoming difficulties in norming real-world audio-visual events.

23.4112 **Cross-modal 'Goodness of Fit' Judgments of Auditory and Visual Meter in Musical Rhythms** Stephen Palmer[1](palmer@cogsci.berkeley.edu), Joshua Peterson[1], Nori Jacoby[2]; [1]Psychology, U. C. Berkeley, [2]Neuroscience, Columbia University

The metrical hierarchy of musical rhythm is defined by the structure of emphases on beats in measures. We investigated 3/4 and 4/4 time signatures in auditory and visual meter using cross-modal goodness-of-fit ratings for visual and auditory probes, respectively. For auditory context conditions, four measures in 3/4 or 4/4 time were defined by a louder beat followed 2 or 3 softer, equally-timed beats, respectively. A visual probe circle occurred in the next four measures at one of 12 phase-angles relative to the auditory downbeat: 0°, 45°, 60°, 90°, 120°, 135°, 180°, 225°, 240°, 270°, 300°, and 315°. Context and probe modalities were reversed for the visual context conditions. Participants rated how well probe stimuli "fit" the rhythmic context in the other modality. Visual contexts showed an expected beat-defined hierarchy, with highest ratings on the downbeat, next-highest for the other beats, and lowest for non-beats. Auditory contexts showed a single broad peak for the downbeat, with little evidence of elevated fit ratings for other beats over non-beats. Similar results were obtained when participants made explicit ratings of cross-modal synchrony using the same stimuli, suggesting a role for purely psychophysical asymmetries in visual vs. auditory processing. Several factors relevant to explaining the asymmetry between these cross-modal conditions are discussed, including faster and more accurate timing information in auditory than visual perception, and increased precision in timing information with additional repetitions of events occurring at regular intervals. Additional data support the relevance of these factors.

Acknowledgement: NSF Grants BCS-1059088

Saturday Afternoon Talks

Attention: Features

Saturday, May 20, 2:30 - 4:15 pm
Talk Session, Talk Room 1
Moderator: Greg Zelinsky

24.11, *2:30 pm* **Seeing physics in the blink of an eye** Chaz Firestone[1](chaz.firestone@yale.edu), Brian Scholl[1]; [1]Department of Psychology, Yale University

People readily understand visible objects and events in terms of invisible physical forces, such as gravity, friction, inertia, and momentum. For example, we can appreciate that certain objects will balance, slide, fall, bend or break. This ability has historically been associated with sophisticated higher-level reasoning, but here we explore the intriguing possibility that such physical properties (e.g. whether a tower of blocks will topple) are extracted during rapid, automatic, visual processing. We did so by exploring both the timecourse of such processing and its consequences for visual awareness. Subjects saw hundreds of block-towers for variable masked durations and rated each tower's stability; later, they rated the same towers again, without time pressure. We correlated these limited-time and unlimited-time impressions of stability to determine when such correlations peak — asking, in other words, how long it takes to form a "complete" physical intuition. Remarkably, stability impressions after even very short exposures (e.g. 100ms) correlated just as highly with unlimited-time judgments as did impressions formed after exposures an order-of-magnitude longer (e.g. 1000ms). Moreover, these immediate physical impressions were accurate, agreeing with physical simulations — and doing so equally well at 100ms as with unlimited time. Next, we exploited inattentional blindness to ask whether stability is processed not only quickly, but also spontaneously and in ways that promote visual awareness. While subjects attended to a central stimulus, an unexpected image flashed in the periphery. Subjects more frequently noticed this image if it was an unstable tower (vs. a stable tower), even though these two towers were just the same image presented upright or inverted. Thus, physical scene understanding is fast, automatic, and attention-grabbing: such impressions are fully extracted in (an exposure faster than) the blink of an eye, and a scene's stability is automatically prioritized in determining the contents of visual awareness.

Acknowledgement: ONR MURI #N00014-16-1-2007

24.12, *2:45 pm* **Strategic Templates for Rejection** Nancy Carlisle[1](nancy.carlisle@gmail.com); [1]Department of Psychology, Lehigh University

Can attention actively suppress a feature? Arita, Carlisle, & Woodman (JEP:HPP, 2012) reported cuing a distractor color sped search (negative cue) compared with neutral cue trials, although the benefit was smaller than typical positive cues. Search arrays contained two colors of objects, where all objects of one color appeared in one hemifield. The negative cue benefit was reduced when search was made easier by reducing the set size. This suggests that attentional templates can be used for active suppression, but only if it is strategically beneficial to use the cue. A failure to replicate calls this conclusion into question. Beck & Hollingworth found no negative cue benefit with mixed colors and suggested the previous results could be explained by a spatial template generated after the search array was presented (JEP:HPP, 2015). Crucially, their manipulation may have reduced the perceived benefit of the negative cue. I created a design with □ of trials in a block with mixed color arrangement (as in Beck & Hollingworth, 2015), and □ of trials with separated arrangement (as in Arita and colleagues, 2012). Importantly, participants did not know which array arrangement would appear, and therefore needed to adopt a strategy based on the utility of the cue for the entire block. I found a main effect of cue type on reaction time ($p < .0001$), with both positive and negative cues leading to significant benefits (p's $< .0001$). Importantly, I found no interaction between cue type and array arrangement ($p = .97$) indicating no difference in the cuing effects based on display arrangement, in contrast to the spatial template hypothesis. My data suggest we can actively suppress a particular feature, but that we may only utilize this control when it is strategically advantageous. This evidence suggests active suppression should be incorporated into theories of attentional control.

24.13, *3:00 pm* **How do we ignore salient distractors?** Clayton Hickey[1](clayton.hickey@unitn.it), Matthew Weaver[1], Hanna Kadel[2], Wieske van Zoest[1]; [1]Center for Mind / Brain Sciences, University of Trento, Italy, [2]Philipps-Universität Marburg, Germany

Our visual environment is too rich for us to deal with at once, so we sample from it by making eye movements. Optimally, we should suppress stimuli that are strategically unimportant so as to ensure that useful objects are fixated first. But there is little actual evidence that distractor suppression plays a role in oculomotor control. Here, we use concurrent recording of EEG and eye-tracking first to determine if distractor suppression fosters efficient eye-movement behaviour. Participants searched for targets presented alongside salient distractors, and we subsequently sorted trials as a function of which stimulus was first fixated. Results show that target-directed saccades are associated not only with enhanced attentional processing of the target, as reflected in the N2pc, but also stronger suppression of the distractor, as indexed in the distractor positivity (Pd). In a subsequent experiment, we build from this finding to investigate the impact of proactive distractor cues. These tell people about the characteristics of non-targets they should ignore before search begins. We find that people are better able to ignore cued distractors, as reflected in saccadic accuracy and reaction time. But, surprisingly, this is associated with a reduction in the distractor-elicited Pd. This suggests that distractor cues do not act by potentiating online attentional suppression, but rather by reducing cortical sensitivity to distractor features before the stimuli appear. We investigate this hypothesis in further time-frequency analyses of EEG data preceding target- and distractor-directed saccades, identifying correlates of oculomotor control in the phase synchronization of parietal alpha and occipital beta. Our results demonstrate the key role of distractor suppression in oculomotor control, pointing at two ways such suppression can be instantiated in the brain.

24.14, *3:15 pm* **More than a filter: Feature-based attention regulates the distribution of visual working memory resources** Blaire Dube[1](bdube@uoguelph.ca), Stephen Emrich[2], Naseem Al-Aidroos[1]; [1]Department of Psychology, University of Guelph, [2]Department of Psychology, Brock University

How does feature-based attention regulate visual working memory (VWM) performance? The prominent filter account proposes that attention acts like a "bouncer" for VWM—the brain's "nightclub"—filtering out distracting information to ensure that access to VWM resources is reserved for relevant information. This account, however, originated from discrete-capacity models of VWM architecture, the assumptions of which have since been challenged. Across three experiments, we revisited the filter account by testing if feature-based attention plays a broader role in regulating VWM performance. Each experiment used partial report tasks in which participants memorized the colors of circle and square stimuli, and we provided a feature-based goal by manipulating the likelihood that one shape would be probed over the other across a range of probabilities. By decomposing participants' responses using mixture and variable-precision models, we estimated the contributions of guesses, non-target responses, and imprecise memory representations to their errors. Consistent with the filter account, participants were less likely to guess when the probed memory item matched the feature-based goal. Interestingly, this effect varied with the strength of the goal, even across high-probabilities where goal-matching information should always be prioritized, demonstrating strategic control over filter strength. Beyond this effect of attention on which stimuli were encoded, we also observed effects on how they were encoded: Estimates of both memory precision and non-target errors varied continuously with feature-based attention. The results demonstrate a new role for feature-based attention in dynamically regulating the distribution of resources within working memory so that the most relevant items are encoded with the greatest precision.

See page 3 for Abstract Numbering System

24.15, *3:30 pm* **Attentional cues potentiate recovery of fine direction discrimination in cortically-blind patients** Matthew Cavanaugh[1,2,3](matthew_cavanaugh@urmc.rochester.edu), Antoine Barbot[2,3], Marisa Carrasco[4], Krystel Huxlin[2,3]; [1]Neuroscience Graduate Program, University of Rochester, [2]Flaum Eye Institute, University of Rochester, [3]Center for Visual Science, University of Rochester, [4]Department of Psychology and Center for Neural Science, NYU

Background. Visual perceptual training in cortically-blind (CB) fields improves performance on trained tasks, recovering vision at previously blind locations. However, contrast sensitivity and fine discrimination remain abnormal, limiting the usefulness of recovered vision in daily life. Here, we asked whether it is possible to overcome residual impairment in fine direction discrimination (FDD) performance by training CB subjects with endogenous, feature-based attention (FBA) cues. Methods. Nine CB subjects were recruited and underwent coarse direction discrimination (CDD) training, followed by FDD training with an FBA cue. Following completion of each training protocol, we tested FDD thresholds at blind-field locations and corresponding intact-field locations, with both neutral and valid FBA cues. T-tests were used to assess significance of differences in FDD thresholds attained after different types of training. Results. Subjects who trained using CDD tasks were able to attain FDD thresholds of 26±5.5° (average±SEM). Training FDD without cues attained FDD thresholds of 18±3.8 deg, not significantly different from those attained following CDD training (26±5.5; p>0.1). Following FDD training with FBA cues, FDD thresholds measured with valid FBA cues (5.4±1.3°) were significantly lower than thresholds attained following FDD training without FBA cues (p=0.02) or CDD training (p=0.01). Moreover, FDD thresholds at blind-field locations for subjects trained and measured with FBA cues were statistically indistinguishable from thresholds at intact-field locations measured with FBA cues (p=0.054) or with neutral FBA cues (p=0.4). Even when measured using neutral FBA cues, FDD thresholds at the blind-field locations trained with FBA cues (9.8±0.2°) were significantly lower than following CDD (p=0.02). Lastly, intact-field thresholds were lower when tested with (3.1±0.3°) than without (4.3±0.7°) FBA cues (p=0.03). Conclusion. Mechanisms governing FBA appear to be intact and functional in CB subjects. Importantly, training with FBA can be leveraged to recover normal, fine visual discrimination performance at trained, blind-field locations.

24.16, *3:45 pm* **Prediction facilitates complex shape processing in visual cortex** Peter Kok[1](pkok@princeton.edu), Nicholas Turk-Browne[1,2]; [1]Princeton Neuroscience Institute,Princeton University, Princeton, NJ, USA., [2]Department of Psychology, Princeton University, Princeton, NJ, USA.

Perception is an inferential process, in which sensory inputs and prior knowledge are combined to arrive at a best guess of what is in the world. In line with this, previous studies have shown that expectations strongly modulate neural signals in sensory cortices. However, most of these studies have focused on expectations about simple features, such as the orientation or spatial location of a grating. This stands in contrast to daily life, where expectations often pertain to more complex objects, such as the expectation of seeing a dog upon hearing a bark. In the current study, we used auditory cues to manipulate the predictability of complex shapes that were defined along a continuum of Fourier descriptors. With high-resolution fMRI, we found that the univariate neural response to invalidly predicted shapes was delayed with respect to validly predicted shapes throughout visual cortex (e.g., in V1, V2, and lateral occipital cortex). Not only was the overall response delayed, but so too was the information present in neural activity patterns. Specifically, we trained an inverted encoding model on shapes in the absence of predictions, and used this model to reconstruct what these visual areas represented when a shape was validly and invalidly predicted. The same shape was presented in both cases, but there was a marked delay in information about this shape when it was invalidly predicted. These results suggest that invalid expectations interfere with shape processing throughout the visual cortical hierarchy. Moreover, the fact that predictions about complex shape change the timing of neural responses stands in contrast to the effect of predictions about simple features, which modulate the amplitude of response. This discrepancy suggests that different neural mechanisms may underlie expectations of varying complexity, which could be related to different sources of object vs. feature expectations in the brain.

Acknowledgement: This work was supported by The Netherlands Organisation for Scientific Research (NWO, Rubicon grant 446-15-004) to P.K. and NIH grant R01 EY021755 to N.B.T-B.

24.17, *4:00 pm* **Computing Saliency over Proto-Objects Predicts Fixations During Scene Viewing** Yupei Chen[1](yupei.chen@stonybrook.edu), Gregory Zelinsky[1,2]; [1]Department of Psychology, Stony Brook University, [2]Department of Computer Science, Stony Brook University

Most models of fixation prediction operate at the feature level, best exemplified by the Itti-Koch (I-K) saliency model. Others suggest that objects are more important (Einhäuser et al., 2008), but defining objects requires human annotation. We propose a computationally-explicit middle ground by predicting fixations using a combination of saliency and mid-level representations of shape known as proto-objects (POs). For 384 real-world scenes we computed an I-K saliency map and a proto-object segmentation, the latter using the model from Yu et al. (2014). We then averaged the saliency values internal to each PO to obtain a salience for each PO segment. The maximally-salient PO determined the next fixation, with the specific x,y position being the saliency-weighted centroid of the PO's shape. To generate sequences of saccades we inhibited fixated locations in the saliency map, as in the I-K model. We found that this PO-saliency model outperformed ($p < .001$) the I-K saliency model in predicting fixation-density maps obtained from 12 participants freely viewing the same 384 scenes (3 seconds each). Comparison to the GBVS saliency model showed a similarly significant benefit. Over five levels we also manipulated the coarseness of the PO segmentations for each scene on a fixation-by-fixation basis, meaning that the first predicted fixation was based on the coarsest segmentation and the fifth predicted fixation was based on the finest. Doing this revealed considerable improvements relative to the other tested saliency models, largely due to the capture of a relationship between center bias and ordinal fixation position. Rather than being an ad hoc addition to a saliency model, a center bias falls out of our model via its coarse-to-fine segmentation of a scene over time (fixations). We conclude that fixations are best modeled at the level of proto-objects, which combines the benefit of objects with the computability of features.

Acknowledgement: This work was supported by NSF grant IIS-1161876 to G.J.Z.

Motion: Flow, Biological, and Higher-Order

Saturday, May 20, 2:30 - 4:15 pm
Talk Session, Talk Room 2
Moderator: Michael Morgan

24.21, *2:30 pm* **Viewpoint oscillation frequency influences the perception of distance travelled from optic flow** Martin Bossard[1](bossard.martin@gmail.com), Cédric Goulon[1], Daniel Mestre[1]; [1]Aix-Marseille Université, CNRS, ISM UMR 7287, Marseille, France

In everyday life, humans and most animals need to navigate in their environment, which produces multiple sources of perceptual information, such as locomotor cues (i.e. proprioceptive, efference copy and vestibular cues) and optic flow. However, few studies focused on the role of the visual consequences of walking (bob, sway, and lunge head motion) on self-motion perception. In a previous study, in which static observers were confronted to a visual simulation of forward motion, we have shown that adding rhythmical components to an optic flow pattern improved the accuracy of subjects' travelled distance estimations, in comparison with a purely translational flow. These results were attributable to the fact that oscillations may increase the global retinal motion and thus improve vection. Another hypothesis was that, walking step frequency being a significant cue in speed perception, visual consequences of step frequency might be at the origin of better estimations.To test this, we used the same experimental procedure in which observers, immersed inside a 4-sided CAVE, had to indicate when they thought they had reached a previously seen target. We tested whether different oscillation frequencies would affect the perception of distance travelled. Observers were confronted with 4 conditions of optic flows simulating forward self-motion. The first condition was generated by purely translational optic flow, at constant speed. The three other conditions of flows were vertical triangular oscillations with three kinds of

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frequencies added to linear forward motion, at the same forward speed. Results show that two groups can be distinguished. Regarding the first group, as in the previous study, adding rhythmic components improves the perception of distance travelled. For the second group, the higher the frequency, the earlier the answers, suggesting that these subjects related the oscillation frequency to their step frequency and perceived themselves as moving faster.

24.22, *2:45 pm* **Optic flow and self-motion information during real-world locomotion** Jonathan Matthis[1](matthis@utexas.edu), Karl Muller[1], Kathryn Bonnen[1], Mary Hayhoe[1]; [1]Center for Perceptual Systems, University of Texas at Austin

A large body of research has examined the way that patterns of motion on the retina contribute to perception of movement through the world, but the actual visual self-motion stimulus experienced during real-world locomotion has never been measured. We used computer vision techniques to estimate optic flow from a head-mounted video camera recorded when subjects walked over various types of real-world terrain. Eye movements and full body kinematics were also recorded. We found that the optic flow experienced during locomotion reveals a pulsing pattern of visual motion that is coupled to the phasic acceleration patterns of the gait cycle. This pulsing optic flow pattern is not present in the constant-velocity flow fields that are generally used to simulate self-motion. This difference between real-world and simulated visual self-motion has important consequences on the behavior of the focus of expansion (FOE) during locomotion, which has been extensively studied as an key locus of information about heading direction but has not been recorded during natural behavior. Results show that the acceleration patterns of the head cause the FOE to follow a complex path in the visual field, in contrast to simulated constant-velocity self-motion stimuli wherein the FOE lies in a stable location in observer's environment. To examine how task-relevant locomotor variables could be derived from real-world stimuli, we processed the head-mounted videos using biologically plausible models of motion sensitive areas in visual cortex. The resulting patterns of simulated neural activity are complex, but display a clear coupling to the bipedal gait cycle. By comparing the resulting patterns of simulated neural activity across different time scales to subjects' kinematics, we found features that correlate with locomotion-relevant variables such as heading direction. We also found features of the visual motion stimulus that may play an important role in postural stability during locomotion over rough terrain.

Acknowledgement: NIH 1T32 - EYE021462, NIH R01 - EY05729

24.23, *3:00 pm* **Visual-vestibular detection of curvilinear paths during self-motion** John Perrone[1](jpnz@waikato.ac.nz); [1]The School of Psychology, The University of Waikato, New Zealand

Humans are able to navigate through cluttered environments while avoiding obstacles in their way. How this occurs is still unknown despite many years of research. It is well established that the visual image motion on the back of the eyes (vector flow field) can be used to extract information about our trajectory (e.g., heading) as well as the relative depth of points in the world but that rotation of the eye/head or body confounds this extraction process. We have previously shown how local efference signals regarding eye or head movements can be used to compensate for the perturbations in image motion caused by the rotation (Perrone & Krauzlis, JOV, 2008). However, movement of the body along curved paths also introduces visual rotation, yet the mechanisms for detecting and compensating for this remain a mystery. The curvilinear signals from the primate vestibular system that have so far been measured indicate insufficient precision for a direct compensatory role. A curvilinear path generates a flow vector (T+R, θ) made up of a translation and rotation component. We need to find (R, φ) which provides the body's curvilinear rotation rate and direction. I have discovered that there exists a trigonometric relationship linking the flow vector to the curvilinear rate, i.e., $R = (T+R)\sin(\alpha - \theta)/\sin(\alpha - \varphi)$. Here, α is a function of the heading. The body's curvilinear rotation can be found by sampling many vectors and testing a sparse array of heading directions (α). However, this purely visual solution occasionally produces errors in the (R, φ) estimates. Model simulations show that broadly tuned vestibular signals for the values of α, R and φ are sufficient to eliminate these errors. Model tests against existing human psychophysical data revealed comparable curvilinear rotation estimation precision. Combined visual-vestibular signals produce greater accuracy than each on its own.

24.24, *3:15 pm* **Residual Perception of Biological Motion in Cortical Blindness** Meike Ramon[1](meike.ramon@gmail.com), Nicolas Ruffieux[1], Junpeng Lao[1], Françoise Colombo[2], Lisa Stacchi[1], François-Xavier Borruat[3], Ettore Accolla[2,3,4], Jean-Marie Annoni [2,3,4], Roberto Caldara[1]; [1]University of Fribourg, Eye and Brain Mapping Laboratory, Department of Psychology, Rue P.-A.-de-Faucigny 2, 1700 Fribourg, Switzerland, [2]Fribourg Hospital, Unit of Neuropsychology and Aphasiology, CP, 1708 Fribourg, Switzerland, [3]Jules-Gonin Ophtalmological Hospital, Neuro-Ophthalmology Unit, University of Lausanne, Avenue de France 15, 1004 Lausanne, Switzerland, [4]University of Fribourg, Laboratory for Cognitive and Neurological Sciences, Department of Medicine, Ch. du Musée 5, 1700 Fribourg, Switzerland

The ability to perceive biological motion (BM) relies on a distributed network of brain regions and can be preserved after damage to high-level visual areas. However, whether it can withstand the loss of vision following bilateral striate damage remains unknown. Here we tested categorization of human and animal BM in BC, a rare case of cortical blindness after anoxia-induced bilateral striate damage. The severity of his impairment, encompassing various aspects of vision and causing blind-like behavior, contrasts with a residual ability to process motion (for a video demonstration see perso.unifr.ch/roberto.caldara/VSS/BC_patient.mov). We presented BC with static or dynamic point-light displays (PLDs) of human or animal walkers. These stimuli were presented individually, or in pairs in two alternative forced choice (2AFC) tasks. Confronted with individual PLDs, BC was unable to categorize the stimuli, irrespective of whether they were static or dynamic. In the 2AFC task, BC exhibited appropriate gaze towards diagnostic information, but performed at chance level with static PLDs, in stark contrast to his ability to efficiently categorize dynamic biological agents. This striking ability to categorize BM provided top-down information is important for at least two reasons. Firstly, it emphasizes the importance of assessing patients' (visual) abilities across a range of task constraints, which can reveal potential residual abilities that may in turn represent a key feature for patient rehabilitation. Our findings reinforce the view that the BM processing network can operate despite severely impaired low-level vision, emphasizing that processing dynamicity in biological agents is a robust feature of human vision.

24.25, *3:30 pm* **Who's chasing whom?: Changing background motion reverses impressions of chasing in perceived animacy** Benjamin van Buren[1](vanburenb@gmail.com), Brian Scholl[1]; [1]Department of Psychology, Yale University

Visual processing recovers not only seemingly low-level features such as color and orientation, but also seemingly higher-level properties such as animacy and intentionality. Even abstract geometric shapes are automatically seen as alive and goal-directed if they move in certain ways. What cues trigger perceived animacy? Researchers have traditionally focused on the local motions of objects, but what may really matter is how objects move with respect to the surrounding scene. Here we demonstrate how movements that signal animacy in one context may be perceived radically differently in the context of another scene. Observers viewed animations containing a stationary central disc and a peripheral disc, which moved around it haphazardly. A background texture (a map of Tokyo) moved behind the discs. For half of observers, the background moved generally along the vector from the peripheral disc to the central disc (as if the discs were moving together over the background, with the central disc always behind the peripheral disc); for the other half of observers, the background moved generally along the vector from the central disc to the peripheral disc. Observers in the first condition overwhelming perceived the central disc as chasing the peripheral disc, while observers in the second condition experienced the reverse. A second study explored objective detection: observers discriminated displays in which a central 'wolf' disc chased a peripheral 'sheep' disc from inanimate control displays in which the wolf instead chased the sheep's (invisible) mirror image. Although chasing was always signaled by the wolf and sheep's close proximity, detection was accurate when the background moved along the vector from the sheep to the wolf, but was poor when the background moved in an uncorrelated manner (controlling for low-level motion). These dramatic context effects indicate that spatiotemporal patterns signaling animacy are detected with reference to a scene-centered coordinate system.

Acknowledgement: ONR MURI #N00014-16-1-2007

 SEE PAGE 3 FOR ABSTRACT NUMBERING SYSTEM

24.26, *3:45 pm* Non-retinotopic feature integration is mandatory and precise Leila Drissi Daoudi[1](leila.drissidaoudi@epfl.ch), Haluk Öğmen[2], Michael Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, [2]Department of Electrical & Computer Engineering, University of Denver, Denver, USA

Visual features can be integrated across retinotopic locations. For example, when a Vernier is followed by a sequence of flanking lines on either side, a percept of two diverging motion streams is elicited. Even though the central Vernier is unconscious due to metacontrast masking, its offset is visible at the following elements. If an offset is introduced to one of the flanking lines, the two offsets integrate (Otto et al., 2006). Here, by varying the number of flanking lines and the position of the flank offset, we show that this integration lasts up to 450ms. Furthermore, this process is mandatory, i.e, observers are not able to consciously access the individual lines and change their decision. These results suggest that the contents of consciousness can be modulated by an unconscious memory-process wherein information is integrated for up to 450ms. This mandatory and unconscious process is not sluggish, but very precise. By using parallel streams, we show that even for spatially very close stimuli the offsets do not spill over. Offsets integrate only when presented in the same stream. Hence, these results suggest that non-retinotopic feature integration is a very precise mechanism, and that the streams create a spatio-temporal window of unconscious, mandatory integration that lasts up to 450ms.

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24.27, *4:00 pm* Attraction and Repulsion Between Local and Global Motion Michael Morgan[1](m.morgan@city.ac.uk), Joshua Solomon[1]; [1]Applied Vision Research Centre, City, University of London

The interaction between local and global motion was studied with moving, circular clouds of dots, which could also move within the cloud. If the cloud moved near-vertically downwards (~270 deg) but the dots within it moved obliquely (240 or 300 deg) the apparent path of the cloud was attracted to that of the dots, as previously demonstrated with moving Gabor patches (Tse & Hseih, 2006; Lisi & Cavanagh, 2015). This attractive effect was enhanced in parafoveal viewing. A larger effect in the opposite direction (repulsion) was found for the perceived direction of the dots when they moved near-vertically (~270 deg) and the cloud containing them moved obliquely (240 or 300 deg). These results are discussed in relation to Gestalt principles of perceived relative motion, and more recent Bayes-inspired accounts of the interaction between local and global motion.

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Visual Search: Other

Saturday, May 20, 5:15 - 6:45 pm
Talk Session, Talk Room 1
Moderator: Arni Kristjansson

25.11, *5:15 pm* If I showed you where you looked, you still wouldn't remember Avi Aizenman[1](avigael_aizenman@berkeley.edu), Ellen Kok[2,3], Melissa Vo[4], Jeremy Wolfe[2]; [1]Vision Science, University of California, Berkeley, [2]Brigham and Women's Hospital/Harvard Medical School, [3]School of Health Professions Education, Maastricht University, [4]Scene Grammar Lab, Goethe University

Observers are no better at reporting where they just fixated in an image than they are at guessing where someone else has fixated. We investigated whether providing participants with explicit, online information about where they looked during a search task would help them recall their own eye movements afterwards. Seventeen observers searched for various objects in "Where's Waldo" images for 3s. On 2/3rds of scenes, observers made target present/absent responses afterwards. On the other third, however, they were asked to click twelve locations in the scene where they thought they had just fixated. Half of the scenes were presented normally (control). In the other half, we employed a gaze-contingent window that gave the impression of a roving 7.5 deg "spotlight" that illuminated everything fixated, while the rest of the display was still visible but darker. To measure the fidelity of the memory, we placed a virtual circle around each fixation and each click and measured the overlap. Perfect overlap would represent perfect memory. When modeled with some noise in placing clicks, best fixation produced 66% overlap for an average circle of diameter 2.6 deg. Overlap with randomly generated 'clicks' is chance performance (21% overlap). As in prior work, participants' click performance (28% overlap) was far from ceiling and quite close to chance performance. It was slightly better than the no-spotlight control (26%, p=0.02) in the spotlight condition. Giving observers more information about their fixations by dimming the periphery improved memory for those fixations modestly, at best. Interestingly, 9 of 14 observers queried thought the spotlight improved their memory (even though it didn't). One thought it made matters worse and four reported no subjective difference. Memory for fixations is poor, introspection about that memory is poor, and additional information about fixation does not help much.

Acknowledgement: DFG grant VO 1683/2-1 to author M.L.V.

25.12, *5:30 pm* Peripheral Representations Enhance Dense Clutter Metrics in Free Search Arturo Deza[1](deza@dyns.ucsb.edu), Miguel Eckstein[2]; [1]Dynamical Neuroscience, UCSB, [2]Psychological and Brain Sciences, UCSB

Introduction: Clutter models (Feature Congestion; FS, Rosenholtz et. al 2005; Edge Density, ED, Mack & Oliva, 2004, and ProtoObject Segmentation, PS, Yu et. al, 2014) aim at generating a score from an image that correlates with performance in a visual task such as search. However, previous metrics do not take into account the interactions between the influences of clutter and the foveated nature of the human visual system. Here we incorporate foveated architectures to standard clutter models (Deza & Eckstein, 2016), and assess their ability (relative to unfoveated clutter metrics) to predict multiple eye movement search performance across images with varying clutter. Methods: Observers (n = 8) freely searched for a target (a person, yes/no task) with varying levels of clutter, small targets, and with a 50% probability of target present. Data Analysis: We correlated the clutter scores for images with the time to foveate a target (2 degree radius from target center). Results: We find that Feature Congestion (r=0.45 vs r_FoV=0.72, p< 0.05) and Edge Density (r=0.38 vs r_FoV=0.87, p< 0.05) benefit from inclusion of a foveated (Fov) architecture. ProtoObject Segmentation does not show such improvements. However, the unfoveated ProtoObject Segmentation model correlates just as high with human foveation time as all the other foveated versions: r=0.76 vs r_Fov = 0.38. The dissociation in results across the FC, ED and PS can be explained in terms of differences across models in the spatial density of the representations. ProtoObject Segmentation has spatially coarse intermediate representations leading to little effects from spatial pooling associated with a foveated architecture. Conclusion: Models with spatially dense representation pipelines can benefit from a foveated architecture when computing clutter metrics to predict time to foveate a target during search with complex scenes.

25.13, *5:45 pm* The width of the functional viewing field is sensitive to distractor-target similarity even in efficient singleton search Gavin Ng[1](jng17@illinois.edu), Alejandro Lleras[1], Simona Buetti[1]; [1]University of Illinois at Urbana-Champaign

Contrary to most models of visual search, recent work from our lab showed that variability in efficient search is meaningful and systematic. Reaction times (RTs), which reflect stage one processing times, increase logarithmically with set size, indicating an exhaustive processing of the scene, even in the presence of an easily visible singleton target. This increase is modulated by distractor-target similarity. The functional viewing field (FVF) - the region surrounding fixation from which useful information can be extracted - has been shown to be smaller in inefficient compared to efficient search tasks. Here we show that the size of the FVF, like RTs, is variable even in efficient search tasks. We monitored eye movements as observers discriminated the direction of a singleton target. In higher distractor-target similarity displays, observers' initial saccades landed further away from the target than in low distractor-targetsimilarity displays, even though search was efficient with both types of distractors. Furthermore, observers executed more fixations, indicating that the FVF was smaller in higher distractor-target displays. Interestingly, regardless of distractor-target similarity, observers fixated closer to the target when there were more items in the display. This presumably results from observers switching to a smaller FVF in order to determine the identity of the target once it is located. Additionally, we found that initial saccade latencies (ISLs) were not affected by total

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set size, suggesting that initial processing of the display is not exhaustive but restricted to the FVF. However, the first eye movement was sensitive to distractor type: ISLs were significantly longer for higher distractor-target similarity displays and most of the initial saccades were directed towards the target. Our results show that the size of the FVF is modulated by distractor-target similarity even in efficient visual search, and that this affects the initial processing time of the search display.

25.14, *6:00 pm* **Serial dependence determines object classification in visual search** Mauro Manassi[1](mauro.manassi@berkeley.edu), Árni Kristjánsson[2], David Whitney[1]; [1]University of California, Berkeley, Department of Psychology, Berkeley, CA, USA, [2]Department of Psychology, University of Iceland

In everyday life, we continuously search and classify the environment around us: we look for keys in our messy room, for a friend in the street and so on. A very important kind of visual search is performed by radiologists, who have to search and classify tumors in X-rays. An underlying assumption of such tasks is that search and recognition are independent of our past experience. However, recent studies have shown that our percepts can be strongly biased toward previously seen stimuli (Fischer & Whitney, 2014; Liberman et al., 2014). Here, we tested whether serial dependence can influence search and classification of objects in critical tasks such as tumor detection. We created three objects with random shapes (objects A/B/C) and generated 48 morph objects in between each pair (147 objects in total). Observers were presented on each trial with a random object and were asked to classify the morph as A/B/C. In order to simulate a tumor search task, we embedded the morph in a noisy background and randomized its location. We found that subjects made consistent perceptual errors when classifying the shape on the current trial, seeing it as more similar to the shape presented on the previous trial. This perceptual attraction extended over 15 seconds back in time (up to 3 trials back). In a control experiment, we checked whether this kind of serial dependence is due to response repetition, on some trials asking subjects to press the space bar instead of classifying the object. Serial dependence still occurred from those trials, ruling out a mere response bias. Our results showed that object classification in visual search can be strongly biased by previously seen stimuli. These results are particularly important for radiologists, who search and classify tumors when viewing many consecutive X-rays.

25.15, *6:15 pm* **Searching with and against each other** Diederick Niehorster[1,2](dcnieho@gmail.com), Tim Cornelissen[1,3], Ignace Hooge[4], Kenneth Holmqvist[1,5]; [1]The Humanities Laboratory, Lund University, Sweden, [2]Department of Psychology, Lund University, Sweden, [3]Scene Grammar Lab, Department of Cognitive Psychology, Goethe University Frankfurt, Germany, [4]Department of Experimental Psychology, Helmholtz Institute, Utrecht University, the Netherlands, [5]UPSET, North-West University (Vaal Triangle Campus), South Africa

Although in real life people frequently perform visual search together, in lab experiments this social dimension is typically left out. Collaborative search with feedback about partners' gaze has been shown to be highly efficient (Brennan et al. 2008). Here we aim to replicate previous findings regarding collaborative search strategies and how they change when people compete instead. Participants were instructed to search a jittered hexagonal grid of Gabors for a target with a vertical orientation, among 24 distractors rotated -10 or 10° while being eye-tracked. Sixteen participants completed three conditions: individual, collaborative and competitive search. For collaboration and competition, searchers were paired with another searcher and shown in real-time at which element the other searcher was looking. Searchers were instructed to find the target as fast as possible and received points or a penalty depending on whether they found the correct target. When instructed to collaborate, both searchers received points or a penalty, regardless who responded. During competition, only the searcher who responded was rewarded points or penalized. Early in trials the overlap in visited hexagons between searchers remained low, indicating that searchers formed a collaboration strategy. This strategy resulted in search times that were roughly half that of individual search without an increase in errors, indicating collaboration was efficient. During competition overlap increased earlier, indicating that competing searchers divided the search space less efficiently than collaborating searchers. During competition, participants increased the rate at which they inspected the elements of the display and, despite no longer dividing the search space as efficiently as during collaboration, found targets faster than in the collaboration condition without an increase in errors. We conclude that participants can efficiently search together when provided only with information about their partner's gaze position. Competing searchers found the target even faster, but without a clear strategy.

Acknowledgement: Marcus and Amalia Wallenberg foundation,

25.16, *6:30 pm* **Estimates of a priori power and false discovery rates induced by post-hoc changes from thousands of independent replications** Dwight Kravitz[1](kravitzd@gwu.edu), Stephen Mitroff[1]; [1]Department of Psychology, The George Washington University

Scientific progress relies on accurate inference about the presence (or absence) of an experimental effect. Failures to replicate high-profile studies have elevated concerns about the integrity of inference in psychology research (Nosek et al., 2015). One proposed solution is pre-registering experimental designs before data collection to prevent post-hoc changes that might increase false positives and to increase publication of null findings. However, pre-registration does not always align with the inherently complex and unpredictable nature of research, particularly when a priori power estimates are not sufficient to guide the design of studies. Better a priori power estimates would also increase confidence in interpreting null results. The current study used a massive dataset of visual search performance (>11 million participants, >2.8 billion trials; Airport Scanner, Kedlin Co.; www.airportscannergame.com) to produce empirical estimates of the a priori power of various designs (i.e., number of trials and participants) and to estimate the impact of and appropriate corrections for various post-hoc changes (e.g., retaining pilot data). Dividing the dataset into many thousands of independent replications of various designs allowed estimation of the minimum effect size each design can reliably detect (i.e., a priori power). Application of common post-hoc changes to these thousands of replications, yielded precise estimates of the individual and combined impact of post-hoc changes on false positive rates, which in some cases were >30%. Critically, adjusted p-values that correct for post-hoc changes can also be derived. The approach and findings discussed here have the potential to significantly strengthen research practices, guiding the design of studies, encouraging transparent reporting of all results, and providing corrections that allow flexibility without sacrificing integrity.

Color and Light: Material perception

Saturday, May 20, 5:15 - 6:45 pm
Talk Session, Talk Room 2
Moderator: Sylvia Pont

25.21, *5:15 pm* **Neo's Spoon and Newton's Apples: Prediction of rigid and non-rigid deformations of materials** Lorilei Alley[1](lorilei.alley@psychol.uni-giessen.de), Alexandra Schmid[1], Katja Doerschner[1]; [1]Justus Liebig University Giessen

Throughout life we acquire complex knowledge about the properties of objects in the world. This knowledge allows us to efficiently predict future events (e.g. whether a falling porcelain cup will shatter) and is critical for survival (e.g. predicting if a snake will strike). Vision research is only beginning to understand the mechanisms underlying such complex predictions. We conducted a study to investigate whether the visual system makes predictions about the kinematics of materials based on object shape and surface properties. Stimuli were computer- rendered familiar objects (teacup, chair, spoon, jelly etc.) that we hypothesised would generate strong expectations about their material kinematics when dropped from a height (whether they would shatter, wobble, splash, bounce, etc.). Control stimuli were novel unfamiliar 3D shapes rendered with the familiar objects' surface properties. Utilizing a 'violation of expectation' paradigm, on each trial we showed a static view of the object, followed by a video sequence of the object falling and impacting the ground. The motion was either 'congruent' with the object and material, behaving as expected (e.g. a falling teacup shattered), or 'incongruent', where the kinematics violated potential predictions (e.g. a falling teacup wrinkled like cloth). In a 'static' condition, different observers viewed only the first static frame. Observers used a scale to rate each video clip on 4 adjectives: 'hard', 'gelatinous', 'heavy', and 'liquid'. We analysed whether congruency of the motion affected how fast observers performed the ratings. We computed a predictability score for the 'congruent' outcome by comparing ratings between this condition and the static condition. Stimuli with high predictability scores should gen-

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erate larger surprise effects (i.e. longer RTs), and this is exactly what was found (r =.483, p < .001). Our results demonstrate for the first time that kinematic properties are an integral part of the visual system's representation of material qualities.

Acknowledgement: Sofja Kovalevskaja Award: Alexander von Humboldt Foundation, sponsored by the German Federal Ministry for Education and Research.

25.22, *5:30 pm* Visual perception of elastic behavior of bouncing objects Vivian Paulun[1](Vivian.C.Paulun@psychol.uni-giessen.de), Roland Fleming[1]; [1]Department of Psychology, Justus-Liebig-University Giessen

When an object bounces around a scene, its behavior depends on both its intrinsic material properties (e.g., elasticity) and extrinsic factors (e.g., initial position, velocity). Visually inferring elasticity requires disentangling these different contributions to the observed motion. Moreover, although the space of possible trajectories is very large, some motions appear intuitively more plausible than others. Here we investigated how the visual system estimates elasticity and the typicality of object motion from short (2s) simulations in which a cubic object bounced in a room. We varied elasticity in ten even steps and randomly varied the object's start position, orientation and velocity to gain three random samples for each elasticity. Based on these 30 variations we created two reduced versions of each stimulus, showing the cube in a completely black environment (as opposed to a fully rendered room). In one condition the cube was identical to the original stimulus; in the other, the cube rigidly followed the same path without rotating or deforming. Thirteen observers rated the apparent elasticity of the cubes and the typicality of their motion. We found that observers were good at estimating elasticity in all three conditions, i.e. irrespective of whether the scene provided all possible cues or was reduced to the movement path. Some of the random variations produced more typical representatives of a given elasticity than others. Rigid motion was generally perceived as less typical than full motion. The pattern of ratings is consistent with simple heuristics based on the duration and the speed of the motion: The longer and faster an object moved, the higher was its perceived elasticity. The same measures showed a similar but weaker relation to the true elasticity of the cubes. Analysis of the distribution of many trajectories suggests such heuristics can be inferred through unsupervised learning.

Acknowledgement: This research was supported by the DFG (SFB-TRR-135:

25.23, *5:45 pm* Perceiving gloss behind transparent layers Sabrina Hansmann-Roth[1], Pascal Mamassian[1]; [1]Laboratoire des Systèmes Perceptifs, CNRS UMR 8248, 29 rue d'Ulm, 75005 Paris, France

The image intensity depends on the illumination, the reflectance properties of objects but also on the reflectance and absorption properties of any intervening media. We recently showed (Hansmann-Roth & Mamassian, VSS 2016) that dark backgrounds increase perceived gloss of central patches. We hypothesized that this simultaneous gloss contrast induced by the dark background causes a perceptual shift in the luminance range. Highlights on the central patch appeared brighter, inducing an increase in perceived gloss. In the current study we present the participant with glossy objects behind partially-transmissive materials. The transparent layer causes an achromatic color shift and compression in contrast, which can affect the perception of the specular reflections of the object behind the transparent layer. We rendered objects with various gloss levels and presented them behind four different transparent layers with varying reflectance properties ranging from black to white (constant transmittance: 0.5). We conducted a maximum likelihood conjoint measurement experiment (Knoblauch & Maloney, 2012) and investigated the contamination of different transparent layers on perceived gloss. We presented two objects simultaneously and asked our participants to indicate which object appears glossier. We used the additive model of MLCM, assigned perceptual scale values to each gloss level of the object and to each reflectance level of the transparent layer, and modeled the contribution of both features to perceived gloss. Our results indicate a significant contribution of the transparent layer when estimating gloss. Highlights and lowlights are affected most by the lightest and darkest transparent layer respectively. In conclusion, we show that disentangling the transparent layer from the underlying object results in a form of gloss induction. Both, the intensification of the lowlights by the darkest layer and the increase of brightness of the highlights by the lightest layer induce an increase in perceived gloss.

Acknowledgement: EU Marie Curie Initial Training Network ''PRISM'' (FP7 - PEOPLE-2012-ITN, Grant Agreement: 316746

25.24, *6:00 pm* The interaction between surface roughness and the illumination field on the perception of metallic materials James Todd[1](todd.44@osu.edu), Farley Norman[2]; [1]Department of Psychology, Ohio State University, [2]Department of Psychological Sciences, Western Kentucky University

An important phenomenon in the study of human perception is the ability of observers to identify different types of surface materials. One factor that complicates this process is that materials can be observed with a wide range of surface geometries and light fields. The present research was designed to examine the influence of these factors on the appearance of metal. The stimuli depicted three possible objects that were illuminated by three possible light fields. These were generated by a single point light source, 2 rectangular area lights, or projecting light onto a translucent white box that contained the object (and the camera) so that the object would be illuminated by ambient light in all directions. The materials were simulated using measured parameters of chrome with four different levels of roughness. Observers rated the metallic appearance and shininess of each depicted object using two sliders. The highest rated appearance of metal and shininess occurred for the surfaces with the lowest roughness in the ambient light field, and these ratings dropped systematically as the roughness was increased. For the objects illuminated by point or area lights, the appearance of metal and shininess were significantly less than in the ambient conditions for the lowest roughness value, and significantly greater than in the ambient condition for intermediate values of roughness. We also included a control condition depicting objects with a low roughness and a porcelain reflectance function that had both Lambertian and specular components. These objects were rated as highly shiny but they did not appear metallic. An analysis of the luminance patterns in these images revealed that the primary difference between metal and porcelain occurs near smooth occlusion boundaries, thus suggesting that these regions provide critical information for distinguishing different types of shiny materials.

25.25, *6:15 pm* The interplay between material qualities and lighting Fan Zhang[1](f.zhang-2@tudelft.nl), Huib de Ridder[1], Rene van Egmond[1], Sylvia Pont[1]; [1]Perceptual Intelligence Lab, Industrial Design Engineering, Delft University of Technology

In previous research we tested visual material perception in matching and discrimination tasks, and found multiple material and lighting dependent interactions. We used four basis surface scattering modes, namely diffuse, asperity, forward, and mesofacet scattering, which we represented by covering a same-shaped 3D object with "matte", "velvety", "specular", and "glittery" finishes, respectively. All four birds were photographed in so-called ambient, focus and brilliance lighting, three canonical modes that are commonly used in lighting design. In the current study, we asked observers to judge the 12 stimuli on 9 material qualities terms that are commonly used in material perception studies, namely "matte", "velvety", "specular", "glittery", "hard", "soft", "rough", "smooth", and "glossy", to test 1) whether the naming of the scattering modes we used is proper; 2) whether certain material qualities can be brought out or eliminated by certain canonical types of illuminations. For each term and each stimulus image, we first asked observers to judge whether it was applicable. If they answered "yes", they were asked to rate the term on a scale from 1 to 7. Three repetitions for 12 stimuli and 9 qualities, made 324 trials per observer. In preliminary results with 9 inexperienced observers, we found that 1) "matte" applied to all materials, while "velvety", "specular" and "glittery" specifically applied to those respective materials; 2) for "specular" and "glossy" we found similar judgments; 3) brilliance light brought out glitteriness, specularity, glossiness and smoothness the best; 4) focus light resulted in a small increase in the velvetiness, softness and roughness ratings compared to those for ambient and brilliance light. In further analysis, we will look into how the key stimuli image features can trigger certain perceived qualities and how to design lighting to optimize appearance.

Acknowledgement: This work has been funded by the EU FP7 Marie Curie Initial Training Networks (ITN) project PRISM, Perceptual Representation of Illumination, Shape and Material (PITN-GA-2012-316746).

25.26, *6:30 pm* Integration of color and gloss in surface material discrimination Toni Saarela[1](toni.saarela@helsinki.fi), Maria Olkkonen[1,2]; [1]Institute of Behavioural Sciences, University of Helsinki, [2]Department of Psychology, Durham University

Background: Real-world surfaces differ from each other in several respects, for example, in roughness, diffuse reflectance (color), and specular reflectance (gloss). When identifying and discriminating surface materials, the visual system could use information from several such cues to perform more precisely and consistently across varying viewing conditions. We tested the integration of information from diffuse and specular reflectance in a discrimination task. Methods: Stimuli were spectrally rendered images of 3D shapes with surface corrugation. We independently varied two surface-material "cues": (1) diffuse reflectance, resulting in greenish-to-bluish color variation, and (2) specular reflectance, resulting in matte-to-glossy appearance variation. On each trial, the observer saw a reference and a test stimulus. The reference was near the middle of the color and gloss ranges, with trial-to-trial jitter. In different blocks of trials, the test varied in the color-only, gloss-only, or in one of three intermediate directions. The observer identified the bluer and/or glossier stimulus. We fit psychometric functions to the proportion-bluer/glossier data to estimate discrimination thresholds. To encourage observers to judge surface properties rather than local image cues, different shapes were interleaved, but within each trial the two shapes were identical. Each shape was further rendered with several rotation angles, changing the pattern of colors and specular highlights. On each trial, rotation was selected randomly for each stimulus. Results: Having two cues improved discrimination: Thresholds were lower in the two-cue, compared to the single-cue conditions. Comparison against model predictions revealed that cue integration was less than optimal statistically, falling between the optimal and strongest-single-cue threshold predictions. Conclusion: The visual system can combine information from color and gloss to improve discrimination of surface material, although the integration falls short of statistically optimal. When faced with shape, viewpoint, and material variation, the visual system might rely on a robust but sub-optimal strategy of cue integration.

Acknowledgement: Supported by the Academy of Finland grant 287506.

PERCEPTION AND ACTION: AFFORDANCES

Saturday, May 20, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

26.3001 Categorical selectivity in the visual pathway revealed by fMRI in awake macaques

Vassilis Pelekanos[1,2](vpelekanos@gmail.com), Olivier Joly[1], Robert Mok[1], Matthew Ainsworth[1,2], Radoslaw Cichy[3], Diana Kyriazis[1], Maria Kelly[2], Andrew Bell[1,2], Nikolaus Kriegeskorte[1]; [1]Cognition and Brain Sciences Unit, Medical Research Council , [2]Department of Experimental Psychology, Oxford University, [3]Department of Education and Psychology, Free University Berlin

Neuronal activity in the primate occipito-temporal pathway has been shown to contain information about visual object category. Specifically, recent neuroimaging and electrophysiological studies have revealed that the inferior temporal (IT) cortex contains regions that encode stimuli belonging to one category compared to others. However, the majority of these studies have limited their investigations to higher parts of IT cortex, leaving earlier areas in the visual hierarchy, as well as areas within the occipito-parietal pathway, less thoroughly explored. Here, we used functional magnetic resonance imaging (fMRI) to investigate the neural encoding of object categorisation in awake behaving macaques. We employed an event-related design and presented 3 monkeys with 48 images, consisting of 24 animate (human- and animal- faces and body-parts) and 24 inanimate (objects and places) images. Monkeys were trained to fixate on a cue and received juice reward for maintaining fixation within the frame where the images were presented. For each subject, we collected approximately 1170-1521 volumes per session. We collected about 10 sessions per monkey. Regions of interest included early visual areas (V1, V2, V3, V4), category-selective regions in IT cortex (face-, object-, body-part- “patches”) and dorsal-parietal regions. We used a general linear model to analyse the time series data in which we included the animals’ broken fixations and head motion as nuisance regressors. Consistent with previous studies, we found that the animate-inanimate, face-body parts and the face-inanimate contrasts activated face patches. We also found voxels preferentially activated by objects vs. places in patches along the temporal cortex and, interestingly, in the intraparietal sulcus. We did not find any categorical organisation in areas V1-3, but the animate-inanimate division was observed in V4. Our results suggest that as one moves beyond the striate cortex, a network of visual areas exhibiting a categorical organisation of object representation begins to emerge.

Acknowledgement: European Research Council

26.3002 Grasp Affordances Are Necessary for Enhanced Target Detection Near the Hand

Robert McManus[1](robert.r.mcmanus@ndsu.edu), Laura Thomas[1]; [1]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University

Observers show biases in attention when viewing objects within versus outside of their hands’ grasping space. For example, people are faster to detect targets presented near a single hand than targets presented far from the hand (Reed et al., 2006). While this effect could be due to the proximity of the hands alone, recent evidence suggests that visual biases near the hands could be contingent on both the hands’ proximity and an observer’s affordances for grasping actions (e.g., Thomas, 2015; 2016). The current study examined the role an observer’s potential to act plays in biasing attention to the space near the hands. Sixty-one participants completed a standard Posner cueing task in which targets appeared on the left or right side of the display. Across blocks, participants either placed their non-responding hand near one of the target locations or kept this hand in their laps. Half of the participants completed this task with their hands free, creating an affordance for a grasping action. The remaining participants completed the task with their non-responding hand immobilized by a fingerboard, eliminating their potential to grasp. In the hands-free condition, participants showed faster detection of targets presented near the right hand than when targets were presented far from the hand. However, participants in the hands-immobilized condition were no faster to detect targets near the hands than targets appearing far from the hands. These results suggest that improved target detection is contingent not only on the proximity of the hands to a stimulus, but on the ability to use the hands in a grasping action as well.

Acknowledgement: National Science Foundation NSF BCS 1556336 Google Faculty Research Award

26.3003 Breaking Ground: Effects of Texture Gradient Disruption on the Visual Perception of Object Reach-Ability

Jonathan Doyon[1](jonathan.doyon@usm.edu), Alen Hajnal[1]; [1]Department of Psychology, University of Southern Mississippi

Gibson’s ground theory of space perception (1950) places the density gradient of a surface at the center of distance perception, such that (1) the rate of change in the density of the texture elements of a surface specifies the orientation and slant of a surface relative to an observer, and (2) the magnitude change in density of texture elements surrounding an object compared to the density near the observer specifies that object’s distance from the observer. Sinai, Ooi, and He (1998) investigated this theory as it relates to how the brain might exploit this cue to simplify computations of distance. Their investigations found that observers were more accurate in judging absolute distance, measured by blind-walking, when objects were viewed on a surface of homogenous texture (i.e., continuous texture gradient), as opposed to a surface of heterogenous texture (i.e., an interruption of texture gradient caused by a gap in the surface). Here, we seek to extend this investigation to the perception of an object’s reach-ability. We suspect that continuous texture gradient may be critical in the successful realization of certain affordances (Gibson, 1979). In a table-top reaching task, participants were asked to judge whether an object was reachable in two conditions: (1) when the object rested on a surface with a continuous texture gradient and (2) when the object rested on a surface with an interruption in the texture gradient (i.e., two distinct gradients). Results showed that participants overestimated action capabilities in both conditions, but less so in the heterogeneous condition. As a consequence, participants in the heterogenous condition were also more accurate with respect to their capabilities. This comports with Sinai, Ooi, & He’s findings that distance estimates across discontinuous gradients are smaller than those made across continuous gradients.

26.3004 Bayes meets Gibson: Affordance-based control of target interception in the face of uncertainty

Scott Steinmetz[1](ststein3@gmail.com), Nathaniel Powell[1], Oliver Layton[1], Brett Fajen[1]; [1]Cognitive Science Department, Rensselaer Polytechnic Institute

To be efficient over time in the pursuit of moving targets, humans and other animals must know when to abandon the chase of a target that is moving too fast to catch or for which the costs of pursuing outweigh the benefits of catching. From an affordance-based perspective, this entails perceiving catchability, which is determined by how fast one needs to move to intercept in relation to one’s locomotor capabilities. However, affordances are traditionally treated as categorical (i.e., the action is either possible or not) when in fact the presence of variability in both perception and movement ensures that target catchability is a continuous, probabilistic function. We developed a computational framework that treats interception as a dynamic decision making process under uncertainty. In our dynamic Bayesian model, the pursuer continuously updates its belief about catchability based on informational variables, such as relative target distance and time until the target reaches an escape region. These beliefs shift based on the likelihood of detecting each variable at a given value (plus noise) when the target was catchable and when it was uncatchable. At each moment, the model uses its belief about catchability to decide whether to continue to pursue the target or give up. To evaluate the model, we compared its beliefs about target catchability to the behavior of humans in an experiment in which subjects had to decide whether to pursue or abandon the chase of a moving target (Fajen et al., VSS 2016). In a subset of randomly selected trials, the model’s beliefs closely matched human behavior – that is, the belief reflected high certainty in catchability when subjects pursued

the target and high certainty in uncatchability when subjects gave up. Our framework provides a powerful tool for investigating action-scaled affordances as probabilistic functions of actor-environment variables.

Acknowledgement: ONR N00014-14-1-0359

26.3005 **Towards Affordance-Based Control in Catching Fly Balls: The Affordance of Catchability** Dees Postma[1](d.b.w.postma@gmail.com), Frank Zaal[1]; [1]Center for Human Movement Sciences, University Medical Center Groningen, University of Groningen

After a drive in baseball, it is crucial for the fielding team to get hold of the ball as quickly as possible. The best way to do this is to make a direct catch. However, this might not always be possible. Some fly balls are simply uncatchable. In that case, it might be better to get the ball after the first bounce. The latter situation requires a fielder to employ different timing and coordination from the former, illustrating that perceived catchability could have an effect on locomotor control. Until now, the effects of (un) catchability on running to catch fly balls have received little attention. We aim to formulate an affordance-based control strategy that appreciates the influence of perceived catchability on locomotor control in catching fly balls. A first step in doing so is to identify the factors that cause some fly balls to be catchable and others to be uncatchable. In an experiment, 18 participants were required to intercept 44 fly balls. Some fly balls were catchable whereas others were not. Mixed Effects Regression was used to examine a number of factors possibly related to catchability. The analysis showed that the boundary between catchable and uncatchable fly balls is largely determined by the locomotor qualities of the individual, the distance to be covered and the time available to do so. The present contribution also studied participants' ability to judge catchability. The same participants were presented with another set of 44 fly balls for which they were to indicate whether these would be uncatchable. Importantly, they were allowed to start running before giving their judgment. Participants could judge catchability correctly. Interestingly, their judgments were predominantly given while they already had started running. These findings pave the way towards the formulation of an affordance-based control strategy for running to catch fly balls.

Acknowledgement: University Medical Center Groningen

26.3006 **Learning affordances through action: Evidence from visual search** Greg Huffman[1](greg.huffman@mail.utoronto.ca), Jay Pratt[1]; [1]University of Toronto

It has long been thought that objects are processed according to affordances they offer. Much of the evidence for this conclusion, however, comes from studies that used images of tools that participants may or may not have previous experience interacting with. Moreover, many tools are spatially asymmetric, adding a further potential confound. In the current study, we eliminated these confounds by using simple geometric stimuli and having participants learn that certain color-shape combinations afforded successfully finishing a task whereas others did not. The learning trials began with a small circle (the 'agent') surrounded by two circles and two squares that were blue or yellow and were contained with a '+' shaped structure. The participant's task was to move the agent, using the arrow keys, past the shapes, out of the structure. Importantly, two of these color-shape combinations allowed the agent to pass (doors) while the other two stopped the agent (walls). To measure whether doors were preferentially processed after affordances were learned, the test trials had participants search for a 'T' among 'L's that were presented on the same color-shape combinations. Evidence for affordance processing would be found if responses times were shorter for targets appearing on doors than targets on walls. The data supported this hypothesis, indicating that not only do affordances guide object processing, but also that affordances can be learned and assigned to otherwise arbitrary stimuli. The response time benefit may reflect a search bias with the attentional system prioritizing the processing of previously action relevant stimuli.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

26.3008 **Action-Specific Effects in Perception and their Mechanisms** Jessica Witt[1](jessica.witt@colostate.edu), Nathan Tenhundfeld[1], Marcos Janzen[1], Michael Tymoski[1], Ian Thornton[2]; [1]Department of Psychology, College of Natural Sciences, Colorado State University, [2]Department of Cognitive Science, University of Malta

Spatial perception is influenced by the perceiver's ability to act. For example, distances appear farther when traversing them requires more energy, and balls appear to move faster when they are more difficult to block. Despite many demonstrations of action-specific effects across a wide range of scenarios, little is known about the mechanism underlying these effects. To explore these mechanisms, we leveraged individual differences with the idea that if a common mechanism underlies two tasks, outcomes on these tasks should be highly related. We found that the magnitude of the two action-specific effects described as examples did not correlate with each other ($r = .15$, $p = .19$). This suggests unique mechanisms underlying energetic-based and performance-based action-specific effects. Furthermore, the magnitude of each effect correlated with perceptual precision within the task ($r = .31$, $r = .40$, $ps < .001$) but not with perceptual precision in the other task ($rs < .03$). This pattern is consistent with a Bayesian mechanism such that when visual information is less reliable, the perceptual system places greater weight on other sources of information such as those from the motor system. In addition, performance on a biological motion perception task did not correlate with the magnitude of either action-specific effect ($rs < .03$). This lack of relationship suggests that the processes involved in connecting the motor system to the visual system to perceive biological motion are not the same processes that connects the motor and visual systems to perceive distance or speed. These data are the first to suggest different mechanisms underlying the different kinds of action-specific effects and to suggest multiple types of connections from the motor system to the visual system.

Acknowledgement: National Science Foundation (BCS-1348916 and BCS-1632222)

26.3009 **Distance on hill overestimation is not influenced by hiking experience** Janzen Janzen[1](mjanzen@colostate.edu), Tenhundfeld Nathan[1], Tymoski Michael[1], Witt Jessica[1]; [1]Colorado State University

Previous research has found that perceptual estimations are scaled by one's ability to act and by the associated costs related to this action. For example, distances on a hill are judged as being farther than distances on the flat, due to the higher metabolic costs associated with traversing hills. One's ability to act may vary according to several different factors, such as age, body size, body control, energetic potential, and task requirements. The extent to which one's ability to act affects spatial perception and which factors specifically contribute to the variation of estimations might provide insight into the underlying mechanisms that rule action-specific perception. In a previous study, we hypothesized that participants with more experience walking up hills would judge distances on hills more accurate, while less experienced participants would overestimate distances on hills. Previous results indicated that experienced hikers did not overestimate distances on hills when visually matching them to distances on the flat. In this study, we aimed to replicate that finding, and to include other factors that have previously been shown to influence distance estimation. Participants visually matched distances on a hill to distances on flat ground in VR and answered a survey on hiking experience. Replicating the main effect, participants overestimated distances on the hill. Contrary to our hypothesis, hiking experience did not modulate overestimation on hills, nor did BMI, or percent of body fat/muscle, contrary to previous research. This study utilized a highly reliable measure which imbues confidence in interpreting this null result. Considering the very high reliability of 0.96, these results suggest that the distance-on-hill effect is robust, and that previous experience does not influence this effect.

26.3010 **I Can't Afford Both: Walk-through-ability Affordance Judgments do not Correlate to the Distance on Hill Effect** Michael Tymoski[1](tymoski@rams.colostate.edu), Jessica Witt[4], Nathan Tenhundfeld[2], Marcos Janzen[3]; [1]Colorado State University

Previous research has shown that visual perception is fundamentally linked to information about the perceiver's body. The ecological approach to visual perception states that perception of affordances (i.e. environmental cues about action capabilities) is anchored to physical dimensions of the perceiver's body in a task relevant way, while the action-specific account for visual perception states that visual perception is linked to internal cues about action capability. For instance, the "distance on hill (DoH)" effect demonstrates that distance judgments are bioenergetically scaled, such that distances on hills are perceived as farther than equal distances on flat ground, due to the increased energy requirement to walk the distance on a hill versus on flat ground. Both theories posit that cues related to the perceiver's body and its potential for action modulate visual perception. However, this theoretical convergence is unexplored. We conducted an individual differences study by comparing participants' performance on a DoH task and an affordance task. For the DoH paradigm participants were presented a virtual hill on an Oculus Rift DK2. They then performed a visual matching task on the egocentric distance to both a cone on the hill and a cone on the flat ground. As expected, distances on hills were judged to be farther away than distances on flat ground, $F(1,158)=85.25$, $p< .001$. For the affordance paradigm, participants made judgments on their ability to walk through a doorway aperture. Their affordance judgments were correlated with their actual abilities, $r=.456$, $p< .001$. However, when we compared performance on these two tasks, there was no significant correlation between DoH effect and accuracy of affordance judgements, $r=.014$, $p=.859$. These data suggest that, although the action specific and ecological accounts for visual perception theoretically converge, they do not employ the same underlying mechanism.

26.3011 **An uphill battle: Distances are reported as farther on a hill even when immediate feedback about estimation accuracy is provided** Nathan Tenhundfeld[1](nlt4au@rams.colostate.edu), Jessica Witt[1]; [1]Cognitive Psychology, Natural Sciences, Colorado State University

Studies have reported distances are seen as farther on a hill than on the flat ground. These studies are part of a larger theoretical framework that suggests your ability to act changes how you see the world. However, this framework has been met with controversy. Critics suggest the reported 'distance-on-hill' effect may be nothing more than response bias. One effective method used to eliminate response biases is to provide feedback about the accuracy of the perceptual judgments. We used an Oculus Rift DK2, head mounted virtual reality system to present the stimuli. Participants were tasked with visually matching the perceived egocentric distance between a cone placed on a virtual hill, and a cone placed on the virtual flat ground. After each trial they were given feedback which told them if their estimate was too far, too close, or correct (which was defined as being within 30cm of the actual distance). Results indicated that despite the feedback there was still an overall significant main effect for the hill on perceived distance, $F(1, 40) = 19.36$, $p < .001$. This suggests that even though participants were given accurate feedback to correct their estimations, they were still unable to resist the distance-on-hill effect. The main effect for distance on the difference scores was also significant $F(1, 40)$ 73.75, $p < .001$. As the distance to the target cone increased, so too did the effect of the hill (versus flat ground). This provides further substantiation for an energetic account of the distance-on-hill effect. Taken together, this replication of the distance-on-hill effect in virtual reality, and the effect's resistance to immediate feedback on estimation accuracy, provides evidence for a perceptual account and helps rule out a response bias account for the effect of action on perception.

Acknowledgement: NSF

26.3012 **Support for modulation of visuomotor processes in shared, social space: Non-human distractors do not influence motor congruency effects relating to object affordances** Elizabeth Saccone[1](elizabeth.saccone@flinders.edu.au), Owen Churches[1], Ancret Szpak[1], Mike Nicholls[1]; [1]School of Psychology, Flinders University of South Australia

Recent research suggests close, interpersonal proximity modulates visuomotor processes for object affordances in shared space. In our previous study, manipulable object stimuli in reachable space elicited motor congruency effects for participants acting alone, but when a co-actor stood opposite, only objects nearest the participant produced motor congruency effects. An alternative, non-social mechanism may explain these findings, however. Perhaps participants perceived the co-actor as a distractor they attempted to ignore, and in doing so neglected the space and stimuli nearby. The current study addressed this alternative explanation with a non-social version of the original experiment, employing non-human distractor items in place of the co-actor. Participants stood at a narrow table, viewing images of household objects on a flat screen. Participants responded to the upright or inverted orientation of objects with left- or right-facing handles. Objects appeared in one of two locations, either nearer or farther from the participant's side of the table. Participants performed the task both alone and with a Japanese waving cat statue (Experiment 1) or a digital metronome (Experiment 2) placed opposite. Both experiments produced the typical object affordance congruency effect; a response advantage when left/right response hand matched the object's left/right handle orientation. In Experiment 1, the cat statue elicited a similar but statistically nonsignificant pattern of results to the original, social study, perhaps reflecting participants' anthropomorphisation of the cat. Accordingly, Experiment 2 employed a distractor that was devoid of human-like features (metronome). The affordance congruency effect emerged but was not modulated by stimulus proximity and metronome presence. These results support past findings indicating social modulation of object affordances in near-body space. Together with the previous study, these results provide an important step towards understanding how visuomotor processes operate in real-world, social contexts and have broad implications for object affordance, joint action and peripersonal space research.

26.3013 **Memory for real objects is better than images – but only when they are within reach** Michael Compton[1](mcompton@unr.edu), Jacqueline Snow[1]; [1]The University of Nevada, Reno

Previous studies of human memory have focused on stimuli in the form of two-dimensional images, rather than tangible real-world objects. Previously, we found a memory advantage for real-world objects versus colored photographs of the same items. A potential explanation for this 'real object advantage' (ROA) is that real objects (but not their representations) afford genuine physical interaction. Here, we examined directly whether the ROA is influenced by reachability by comparing memory performance for images versus real objects, when they are presented either within versus outside of reach. Participants were asked to memorize 112 different objects: half were real objects and the remainder were high-resolution color images of objects. Half of the stimuli in each display format were presented within reach, and the remainder were outside of reaching distance. The images were matched closely to the real objects for size, viewing angle, background and illumination. Participants completed a free recall task, a recognition task, and also a task in which they indicated whether the object was displayed as a real object or an image. We predicted that if graspability is important in driving the ROA, then stimuli positioned beyond reach should have no influence on memory for images, but should impair memory for real objects. In line with this prediction, we found that free recall for real objects was superior to images, but only when the objects were within reach. Conversely, recall for images was unaffected by distance, suggesting that the effect for the real objects was not attributable to distance-related changes such as retinal size. A similar pattern was observed in participants' ability to indicate the format in which the stimuli were presented Reachability is a critical determinant of the ROA.

Face Perception: Models

Saturday, May 20, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

26.3014 **Coding of faces by tensor components** Sidney Lehky[1,3](sidney@salk.edu), Anh Huy Phan[2], Andrzej Cichocki[2], Keiji Tanaka[1]; [1]Cognitive Brain Mapping Laboratory, RIKEN Brain Science Institute, [2]Advanced Brain Signal Processing Laboratory, RIKEN Brain Science Institute, [3]Computational Neurobiology Laboratory, Salk Institute

Neurons selectively responsive to faces exist in the ventral visual stream of both monkeys and humans. However, the characteristics of face cell receptive fields are poorly understood. Here we use tensor decompositions of faces to model a range of possibilities for the neural coding of faces that may inspire future experimental work. Tensor decomposition is in some sense a generalization of principal component analysis from 2-D to higher dimensions. For this study the input face set was a 4-D array, with two spatial dimensions, color the third dimension, and the population of different faces forming the fourth dimension. Tensor decomposition of a population of faces produces a set of components called tensorfaces. Tensorfaces can be used to reconstruct different faces by doing different weighted combinations of those components. A set of tensorfaces thus forms a population code for the representation of faces. A special feature of the tensor decomposition algorithm we used was the ability to specify the complexity of the tensorface components, measured as Kolmogorov complexity (algorithmic information). High-complexity tensorfaces have clear face-like appearances, while low-complexity tensorfaces have blob-like appearances that crudely approximate faces. For a fixed population size, high-complexity tensorfaces produced smaller reconstruction errors than low-complexity tensorfaces when dealing with familiar faces. However, high-complexity tensorfaces had a poorer ability to generalize to handling novel face stimuli that were very different from the input face training set. This raises the possibility that it may be advantageous for biological face cell populations to contain a diverse range of complexities rather than a single optimal complexity.

26.3015 Identifying ‘Confusability Regions’ in Face Morphs Used for Ensemble Perception

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The ability to extract summary statistics from a set of similar items, a phenomenon known as ensemble perception, is an active area of research. In exploring high-level ensemble domains, such as the perception of average expression, researchers have often utilized gradually changing face morphs that span a circular distribution (e.g., happy to sad to angry to happy). However, in their current implementation, face morphs may unintentionally introduce noise into the ensemble measurement, leading to an underestimation of ensemble perception abilities. Specifically, some facial expressions on the morph wheel appear perceptually similar even though they are positioned relatively far apart. For instance, in a morph wheel of happy-sad-angry-happy expressions, an expression between happy and sad may not be perceptually distinguishable from an expression between sad and angry. Without accounting for this perceptual confusability, observer error will be overestimated. The current experiment accounts for this by determining the perceptual confusability of a previously implemented morph wheel. In a 2-alternative-forced-choice task, 7 observers were asked to discriminate between multiple anchor images (36 in total) and all 360 facial expressions on the morph wheel (which yielded close to 27,000 trials per participant). Results are visualized on a ‘confusability matrix’ depicting the images most likely to be confused for one another. This confusability matrix reveals discrimination thresholds of relatively adjacent expressions and, more importantly, uncovers confusable images between distant expressions on the morph wheel, previously unaccounted for. By accounting for these ‘confusability regions,’ we demonstrate a significant improvement in model estimation of previously published ensemble performance, suggesting high-level ensemble abilities may be better than previously thought.

26.3016 The Lightness Distortion Effect: Additive Conjoint Measurement Shows Race Has a Larger Influence on Perceived Lightness of Upright than Inverted Faces

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BACKGROUND African American faces are judged to be darker than Caucasian faces, even when faces are matched for mean luminance and contrast (Levin & Banaji, 2006). This is the Lightness Distortion Effect (LDE), which is found even when faces are blurred, suggesting that low-level visual features drive LDE to at least some degree (Firestone & Scholl, 2015). Here, the LDE is measured using maximum likelihood conjoint measurement (MLCM). Upright and inverted faces were tested separately to control for low-level visual features. METHODS The joint influence of (1) overall mean luminance and (2) race was measured for perceived face lightness. Thirteen African American faces ranging in mean luminance and contrast and 13 Caucasian faces, matched to the African American faces in mean luminance and contrast, were tested (Levin & Banaji, 2006). All pairs of the 26 faces (either upright or inverted, in separate runs) were presented straddling fixation for 250 msec, followed immediately by a noise mask (with replications, 1,800 judgments in all for each observer). Conjoint measurement requires that participants only choose which member of a pair appears lighter; this ameliorates concern about demand characteristics (e.g. Firestone & Scholl, 2015). Perceptual lightness scales for all 26 face stimuli were derived from MLCM. RESULTS & CONCLUSIONS Each observer’s results were analyzed separately. For 5 of the 6 observers, race had a significant effect on lightness judgments of upright faces ($p < 0.001$ for each observer) in the direction of a fixed decrement in perceived lightness for each African American face. Further, the magnitude of this effect was greater for upright than inverted faces for 5 of the 6 observers ($p < 0.05$). The greater effect of race with upright than inverted faces shows that perception of face lightness depends on race beyond just low-level features.

26.3017 Face Representations in Deep Convolutional Neural Networks

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Algorithms based on deep convolutional neural networks (DCNNs) have made impressive gains on the problem of recognizing faces across changes in appearance, illumination, and viewpoint. These networks are trained on a very large number of face identities and ultimately develop a highly compact representation of each face at the network’s top level. It is generally assumed that these representations capture aspects of facial identity that are invariant across pose, illumination, expression, and appearance. We analyzed the top-level feature space produced by two state-of-the-art DCNNs trained for face identification with >494,000 images of 10,575 individuals (Chen, 2016; Sankaranarayanan, 2016). In one set of experiments, we trained classifiers to predict image-based properties of faces using the networks’ top-level feature descriptions as input. Classifiers determined face yaw to within 9.5 degrees and face pitch (frontal versus offset) at 67% correct. Top-level features also predicted whether the input came from a photograph or video frame with 87% accuracy. In a second experiment, we compared top-level feature codes of different views of the same identities to develop an index of feature invariance. Surprisingly, we found that invariant coding was a characteristic of individual identities, rather than individual features - with some identities encoded invariantly whereas others were not. In a third analysis, we used t-Distributed Stochastic Neighbor Embedding to visualize the top-level DCNN feature space for the Janus CS3 dataset (cf. Klare et al., 2015) containing over 69,000 images of 1,894 distinct identities. This visualization indicated that image quality information is retained in the top-level DCNN features, with poor quality images clustering at the center of the space. The representation of photometric details for face images in top-level DCNN features echoes findings of object category-orthogonal information in macaque IT cortex (Hong et al., 2016), reinforcing the claim that coarse codes can effectively represent complex stimulus sets.

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26.3018 Training a deep convolutional neural network with multiple face sizes and positions, but not resolutions, is necessary for generating invariant face recognition across these transformations

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Convolutional neural networks have demonstrated human-like ability in face recognition, with recent networks achieving as high as 97% accuracy (Taigman, 2014). It is thought that non-linear operations (e.g. maximum-pooling) are key for developing position and size invariance (Riesenhuber & Poggio, 1999). However, it is unknown how training contributes to invariant face recognition. Here, we tested how training affects invariant face recognition across position, size, and resolution. We used a convolutional neural network architecture of TensorFlow (tensorflow.org). We trained the network to recognize 101 faces that varied in age, gender, and ethnicity across views (15 views/face, spanning 0 to ±105□). The network was trained on 80% of views, randomly selected, and tested on the remaining 20% of views. During training faces were shown centrally and presented in one size and resolution. Then, we tested face recognition across views for new positions, sizes, and resolutions not shown during training. Results show that face recognition performance progressively declined for faces shown in different positions (Figure 1A) or sizes (Figure 1B) than shown during training. However, face recognition performance general-

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ized across resolutions (Figure 1C). Further experiments using a constant number of training examples, but different training regimes, revealed that training with random positions (Figure 1D) or random sizes (Figure 1E) generated more robust performance than training with faces in 5 positions (Figure 1D) or 5 sizes (Figure 1E). Additionally, the network displayed better performance on faces shown in new sizes than new positions. Overall, our results indicate that the architecture of the neural network is (1) sufficient for invariant face recognition across resolutions, (2) but insufficient for invariant face recognition across size and position unless trained with many faces varying in size and position. By understanding the limits of convolutional neural networks we can gain insights to understanding factors that enable successful face recognition.

26.3019 Using Psychophysical Methods to Study Face Identification in a Deep Neural Network

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Deep neural networks (DNN) have been very effective in identifying human faces from 2D images, on par with human-level performance. However, little is known about how they do it. In fact, their complexity makes their mechanisms about as opaque as those of the brain. Here, unlike previous research that generally treats DNNs as black boxes, we use rigorous psychophysical methods to better understand the representations and mechanisms underlying the categorization behavior of DNNs. We trained a state-of-the-art 10-layer ResNet to recognize 2,000 human identities generated from a 3D face model where we controlled age (25, 45, 65 years of age), emotional expression (happy, surprise, fear, disgust, anger, sad, neutral), gender (male, female), 2 facial orientation axes X and Y (each with 5 levels from -30 to +30 deg), vertical and horizontal illuminations (each with 5 levels from -30 to +30), plus random scaling and translation of the resulting 26,250,000 2D images (see S1). At training, we used two conditions of similarity of images (most similar; most different using subsets of face generation parameters) to test generalization of identity across the full set of face generation parameters. We found catastrophic (i.e. not graceful) degradation of performance in the most different condition, particularly when combining the factors of orientation and illumination. To understand the visual information the network learned to represent and identify faces, we applied Gosselin & Schyns (2001) Bubbles procedure at testing. We found striking differences in the features that the network represents compared with those typically used in humans. To our knowledge, this is the first time that a rigorous psychophysical approach controlling the dimensions of face variance is applied to better understand the behavior and information coding of complex DNNs. Our results inform fundamental differences between categorization mechanisms and representations of DNNs and the human brain.

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26.3020 Picturing Jonah Hill: memory-based image reconstruction of facial identity

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Our memory for human faces has been studied extensively, especially regarding the specific factors that influence face memorability. However, the detailed visual content of the representations underlying face memory remains largely unclear. Additionally, the relationship between face memory and face perception is not well understood given that these two aspects of face processing are typically investigated independently. Accordingly, the current work aimed to examine these issues by adopting an imaging reconstruction approach to estimate the visual appearance of face images from memory and perception-based behavioural data in neurologically healthy adults. Specifically, we used judgements of visual similarity between facial stimuli and between recollections of facial appearance retrieved from memory to construct a joint perceptual-memory face space. The structure of this hybrid representational space was then used to reconstruct the appearance of different facial identities corresponding to both unfamiliar and familiar faces. Specifically, memory-based reconstructions were carried out for newly-learned faces as well as for famous individuals (i.e., media personalities such as Jonah Hill). Our results demonstrated robust levels of memory and perception-based reconstruction performance for all face categories separately in every participant. In particular, we note the ability to reconstruct successfully images corresponding to famous individuals based on information retrieved from long-term memory. Thus, the current work provides a new approach to probing the representational content of face memory. Theoretically, it suggests that memory and perception share a common representational basis and, furthermore, from a translational standpoint, it can open a new path for concrete applications such as computer-based 'sketch artists'.

26.3021 Large inversion effects are not specific to faces and do not vary with object expertise

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Saturday PM

Visual object recognition is impaired when stimuli are shown upside-down. This phenomenon is known as the inversion effect, and a substantial body of evidence suggests it is much larger for faces than non-face objects. The large inversion effect for faces has been widely used as key evidence that face processing is special, and hundreds of studies have used it as a tool to investigate face-specific processes. Here we show that large inversion effects are not specific to faces. We tested two groups of participants, over the web (n=63) and in the laboratory (n=57), with two car tasks tapping basic object recognition and within-class recognition. Both car tasks generated large inversion effects which were identical to those produced by parallel face tasks. For basic-level recognition, the car inversion effects were 28% (SD=12%) and 27% (SD=13%), while the face inversion effects were 28% (SD=13%) and 26% (SD=10%) (web and lab samples, respectively). For within-class recognition, the car inversion effects were 23% (SD=9%) and 26% (SD=10%), while the face inversion effects were 25% (SD=13%) and 25% (SD=10%). Additional analyses showed that the car inversion effects did not vary with car expertise. Our findings demonstrate that non-face object recognition can depend on processes that are highly orientation-specific, challenging a critical behavioral marker of face-specific processes. We suggest that, rather than being face-specific, inversion effects are the result of a special type of processing engaged in recognition of exemplars from complex but highly homogeneous sets of objects with a canonical orientation. Studies which claimed to measure face-specific mechanisms did not control for this type of processing and so will need reexamination.

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26.3022 Initial fixation to faces during gender identification is optimized for natural statistics of expressions

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During face discrimination tasks, observers vary their initial fixation to faces in order to maximize task performance. For gender discrimination of faces with neutral expressions, the optimal point of fixation (OPF) is just below the eyes and is predicted by an optimal Bayesian model that takes into account the foveated nature of the visual system (foveated ideal observer, FIO; Peterson & Eckstein, 2012). Here, we investigate human OPFs for a gender task with an atypical relative frequency of facial expressions (50/50 - happy/neutral) that alters the theoretical OPF predicted by the FIO. Methods: Five observers completed a gender discrimination task with 40 faces (20/20 male/female, and 10 of each with a happy expression) in luminance noise and 15 deg in height. In one condition, observers made free saccades in 3 blocks with presentation times of 350ms. In a second condition (forced-fixation), we assessed the human OPFs for the same task. Observers randomly fixated 1 of 5 horizontally centered positions on the face (forehead, eyes, nose, mouth, and an individual preferred fixation) for 200ms. Results: The forced-fixation condition showed that the human OPF is above the nose tip. However, human initial fixations in the free-saccade condition are suboptimal and directed to a higher point located below the eyes. This is consistent with the OPF for a gender discrimination task using the more frequent neutral-expression faces. Conclusions: Our findings suggest that observers optimize their initial fixation to faces, taking into account the statistics of occurrence of facial expressions. This fixation strategy seems to be inflexible to greatly altered facial expression statistics.

Face Perception: Neural mechanisms

Saturday, May 20, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

26.3023 The importance of image properties in the neural representation of familiar faces

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A full understanding of face recognition must involve identifying the visual information that is used to discriminate different identities and how this is represented in the brain. Previous behavioural studies have shown that the recognition of familiar faces is primarily based on differences in surface properties of the image. Our aim was to explore the importance of surface properties and also shape properties in the neural representation of familiar faces. We took a set of face images and measured variance in the shape and surface properties using principal component analysis (PCA). Face-selective regions (FFA, OFA and STS) were defined in an independent localizer scan. We then showed participants a subset of the face images and measured the resulting patterns of neural response using fMRI. Patterns of response to pairs of images were compared to generate a similarity matrix across all faces in each ROI. Corresponding similarity matrices for shape and surface properties were then created by correlating the PCA vectors across pairs of images. The similarity matrices for shape and surface properties were then used to predict the patterns of neural response in each ROI. Patterns of response in the OFA could be predicted by both the shape and surface properties of the face images. However, patterns of response in the FFA and STS could only be predicted by the shape of the face image. The dissociation between the selectivity for shape in the FFA and previous behavioural findings revealing a preeminent role of surface properties in face recognition suggests that, although the FFA may play a role in the recognition of facial identity, this region is not solely responsible for this process.

26.3024 Fast periodic visual stimulation reveals face familiarity processing across image variability in the human adult brain

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Recognizing a familiar face across widely variable natural images is a fundamental ability for us humans (Burton & Jenkins, 2011). Yet, it is difficult to capture this process reliably, without an explicit behavioural task. Here we designed a fast and automatic approach that required both discriminating highly familiar from unfamiliar faces and generalizing across different images of the same individual face. We recorded high-density electroencephalogram (EEG) at 6 Hz during brief 70 sec sequences of fast periodic visual stimulation (FPVS). During stimulation, unfamiliar faces were presented at 6Hz (base) with familiar (here famous) faces appearing as every 7th image at a stimulation rate of 0.86 Hz. Images showed faces across naturally occurring changes in view, expression or visual appearance. Throughout each sequence, base face identity varied at every stimulation cycle while the 0.86 Hz periodic famous identity stayed the same. Stimulation sequences were also shown at inverted orientation. Clear visual discrimination responses emerged to periodic presentations of the same familiar face over occipito-temporal electrodes. Importantly, familiarity responses were markedly reduced on inverted sequences, ruling out a low-level account. These findings indicate that the human brain can implicitly discriminate familiar from unfamiliar faces at a glance, and generalize across wide image variability. Our data demonstrate that FPVS-EEG is a highly sensitive tool to characterize rapid invariant familiar face recognition in the human brain.

26.3025 Compound facial threat cue perception: Contributions of visual pathways by image size

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Introduction: Relatively greater amygdalar response has been found to rapidly presented fear faces when coupled with averted gaze (offering clear signal of threat location), and to sustained presentations of ambiguous threat (direct gaze fear; Adams et al., 2012). To help explain these results, the parvocellular (P) and magnocellular (M) pathways have been implicated in the processing ambiguous versus clear threat, respectively. We tested another presentation parameter relevant to these visual pathways, manipulating stimulus size as a natural spatial filter (Smith & Schyns, 2009). Methods: Twenty-nine (15 female) participants passively viewed fearful faces in an ABA design alternating between averted and direct gaze, for 16 blocks. Fourteen participants (8 female) were presented small faces (visual angle of 3.9□ by 5˚) while fifteen participants (6 female) were presented large faces (visual angle of 9.7˚ by 12.5 □). Each block consisted of 16 trials; stimuli were presented for 300 ms then a 1200 ms fixation. Results: For small presentations favoring (M) pathway, clear threat (averted gaze fear) minus ambiguous threat (direct gaze fear) yielded activation in many regions, including: right-amygdala, PMC, SMA, left-IFC, right-OFC, thalamus, insula, and left-TPJ. Ambiguous threat-gaze minus clear threat yielded fewer areas of activation including the OFC, right-mPFC, right-ITG, CG, and posterior cingulate. The pattern was in many ways reversed for large stimuli: Ambiguous minus clear threat elicited activation in the amygdala, mPFC regions, right-STS, bilateral-iFG, and right-insula. Clear minus ambiguous threat elicited fewer activations including in the right-insula and SMA, left-caudate, cingulate, and MT. Conclusion: Our findings with small versus large presentations of clear versus ambiguous threat-gaze pairs yielded similar patterns of activations previously found for rapid versus sustained presentations of the same threat-gaze pairs (Adams et al., 2012). These findings highlight that presentation parameters yield highly variable effects, presumably due to differential magnocellular versus parvocellular involvement.

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26.3026 Population receptive field tuning in the human Fusiform Face area

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Introduction. Population receptive field modeling (pRF; Dumoulin & Wandell, 2008) provides a powerful way of estimating the cumulative tuning of the population of cells in a single voxel. PRF models have been used to estimate spatial tuning properties in multiple cortical and subcortical visual areas, auditory frequency tuning, attentional effects, and topographic organization for size/numerosity. Here we examine whether pRF modeling would reveal systematic voxel-wise tuning preferences within the Fusiform Face area (FFA). The FFA is selectively responsive to face vs. non-face stimuli, and individual voxels show preferences for individual faces. However, it is still debated whether neurons with similar tuning preferences for identity are scattered or clustered (Dubois et al., 2015). Methods. Stimuli consisted of 19 distinct pairs of stereotypically Caucasian and African American male faces. Each pair was morphed into 7 equal steps, creating a total of 133 unique faces. Stimuli were histogram equalized for luminance. Using fMRI, we presented subjects with the full stimulus set in each run, and we collected at least 6 runs from each subject (n = 3). For each subject, we used a modified pRF model to estimate each voxel's tuning preference along our morph sequence within functionally defined FFA. Results. All voxels in the functionally defined FFA showed a strong baseline response to all faces. However, for all subjects and hemispheres, voxels also showed replicable (across sessions) tuning along the dimension of race. At a threshold of $r > 0.2$ (corresponding to a 1.25% false discovery rate) 58% (averaged across subjects) of voxels in the left FFA and 62% of voxels in the right FFA showed featural selectivity. Tuning preferences varied smoothly across the cortical surface of the FFA. It remains to be seen whether these topologies show inter-subject consistency or are unique across individuals.

26.3027 Mapping Spatial Preferences in Face and Object Patches in the Rhesus Macaque Using fMRI

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The dorsal visual stream of the brain primarily processes visual spatial information, whereas the ventral visual stream processes the shape, category, and identity of visual objects. In primates, the ventral visual stream contains regions that preferentially respond to visual categories, such as faces and objects. However, even in the ventral visual stream, neural activity can be modulated by the location of an object in the visual field. Early visual areas are retinotopically organized, with many responding preferentially or exclusively to stimuli in the contralateral visual field. Early visual areas can also exhibit a preference for the upper or lower visual field. It is unclear how spatial preferences are retained as information travels down the ventral visual stream. In particular, it is not known whether shape selective areas in the inferior temporal cortex show spatial preferences. To assess the retinotopic dependence of face-selective areas, we measured fMRI responses in two rhesus macaques to the presentation of static monkey faces (and objects) in four quadrants of the visual field during a central fixation task. We evaluated responses in six face-selective areas, many of them in the superior temporal sulcus, and found they all exhibited a similar retinotopic pattern of activation. Activation was greater when complex objects were presented in the contralateral quadrants than in the ipsilateral quadrants of the visual field. Activation was also greater when faces were presented in the lower visual field quadrants than in the upper quadrants. The results suggest that visual field location information is retained throughout the ventral visual stream, and effects the processing of complex shape stimuli such as faces and objects. The preferences also suggest that a face in the lower hemifield of the visual field may be assessed and recognized more consistently than one in the upper half of the visual field.

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26.3028 Face repetition probability does not affect repetition suppression in macaque middle lateral face patch.

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It has been proposed that repetition suppression (i.e. a reduced neural activity when stimuli are repeated) results from a fulfilled expectation of repetition or a reduced prediction error (Summerfield et al., 2008). This implies that repetition suppression should increase when a repetition is expected and decrease when it is unexpected. While this prediction is supported by human functional imaging (fMRI) studies (e.g. Summerfield et al., 2008), no evidence was found in macaque inferior temporal cortex (IT) spiking activity (Kaliukhovich & Vogels, 2011). Here, we tested three possible explanations for this discrepancy by recording spiking activity in macaque IT. First, we performed recordings in face patch ML instead of outside of a face-selective region. Second, we used faces as stimuli. Third, we required our monkeys to perform a task instead of passive fixation. In two experiments, we manipulated the probability of a face repetition (75% or 25%) between blocks of 40 trials. A trial consisted of two face presentations that were either a repetition (same face identity) or an alternation, followed by a saccade response by the monkey to receive a reward. In a first experiment, we included target trials where one face was inverted. The task (did the trial contain an inverted face?) was orthogonal to the manipulation of repetition probability. We observed repetition suppression, but there was no effect of repetition probability on its magnitude (face-selective cells in 2 monkeys). In a further experiment, we made a face repetition relevant to the task (i.e. was the face repeated?). There was a clear performance bias dependent on the probability of a face repetition, but again no effect on the responses (face-selective cells in 1 monkey). In conclusion, regardless of whether a face repetition is explicitly relevant for the monkey, we see no evidence of a prediction error response in ML.

26.3029 The superior temporal sulcus is causally connected to the amygdala: A combined TBS-fMRI study

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Non-human primate neuroanatomical studies have identified a cortical pathway from the superior temporal sulcus (STS) projecting into dorsal sub-regions of the amygdala, but whether this same pathway exists in humans is unknown. Here, we addressed this question by combining thetaburst transcranial magnetic stimulation (TBS) with functional magnetic resonance imaging (fMRI) to test the prediction that the STS and amygdala are functionally connected during face perception. Human participants (N=17) were scanned, over two sessions, while viewing 3-second video clips of moving faces, bodies and objects. During these sessions, TBS was delivered over the face-selective right posterior STS (rpSTS) or over the vertex control site. A region-of-interest analysis revealed results consistent with our hypothesis. Namely, TBS delivered over the rpSTS reduced the neural response to faces (but not to bodies or objects) in the rpSTS, right anterior STS (raSTS) and right amygdala, compared to TBS delivered over the vertex. By contrast, TBS delivered over the rpSTS did not significantly reduce the neural response to faces in the right fusiform face area (rFFA) or right occipital face area (rOFA). This pattern of results is consistent with the existence of a cortico-amygdala pathway in humans for processing face information projecting from the rpSTS, via the raSTS, into the amygdala. This conclusion is consistent with non-human primate neuroanatomy and with existing face perception models. References Pitcher, D., Japee, S., Rauth, L., & Ungerleider, L. G. (In Press). The superior temporal sulcus is causally connected to the amygdala: A combined TBS-fMRI study. Journal of Neuroscience.

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26.3030 A combined fMRI-MEG investigation of face information processing in the occipito-temporal cortex

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The processing of face information involves a distributed functional network of face sensitive areas in the occipitotemporal cortex and beyond. However, we do not yet have a comprehensive understanding of the temporal dynamics of these key regions and their interactions. In this study, we investigated the spatio-temporal properties of face processing in the occipitotemporal cortex using fMRI and Magnetoencephalograpy (MEG). Subjects viewed faces and objects during the experiment. Each subject's face selective regions were localized with fMRI contrasting responses to faces and objects. Their MEG data were analyzed with beamformer method, which allows for an inverse model to obtain MEG source signals. The results show that face-selective areas identified by MEG are highly consistent with that localized by fMRI. More importantly, MEG signals at the various sources reveal an intricate dynamic picture of these hierarchical face sensitive areas. Specifically, the face-selective signal at right Occipital Face Area (rOFA) reaches peak at around 110 ms, and would last longer if face components were rearranged preventing the perception of a wholistic face. Then face information engages the right posterior Fusiform Face Area (pFFA) and onto the anterior aFFA at about 120 ms and 130 ms respectively. Activity in the left fusiform gyrus peaks slightly later than the rFFA, at around 140 ms. Subsequently, a region in the inferior temporal gyrus just lateral to the rFFA is activated, with somewhat more sustained signal and peaking at about 155 ms, with a second peak at around 210 ms. The right posterior Superior Temporal Sulcus (pSTS), presumably more sensitive to dynamic facial properties, reaches peak activity at about 170 ms. Overall, while many studies have propsed the N170 as a key electrophysiological index for face processing, our source-localized MEG data suggest a significantly earlier engagement of the core ventral face-selective areas.

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26.3031 Differential visual pathway contributions to compound facial threat cue processing

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Facial expression can be a threat cue whose meaning depends on the direction of eye gaze. For example, fear combined with averted eye gaze clearly signals threat and its location, while a direct gaze leaves the location ambiguous (Adams et al., 2012). Processing of clear and ambiguous threat cues is thought to differentially involve the major visual pathways: magnocellular (M) pathway for rapid processing of clear threat and parvocellular (P) pathway for slower processing of threat ambiguity (Adams et al., 2012, Kveraga, 2014). Here we sought to characterize neurodynamics while perceiving threat from faces that were biased towards M or P pathways, or unbiased two-tone images. Participants (N=58) viewed a series of direct and averted gaze fearful and neutral displays, each for 1s. We extracted source-localized MEG activity and computed direction of information flow via phase-slope index (PSI) analysis in select regions of the face-processing network: primary visual cortex (V1), fusiform face area (FFA), periamygdaloid cortex (PAC), posterior superior temporal sulcus (pSTS), and orbitofrontal cortex (OFC). We found that early activity in V1 lead activity in FFA ($p=0.001$) and in PAC ($p=0.007$) for P-biased compared to M-biased faces. In fear > neutral faces, activity in left PAC and FFA was modulated by pathway, with PAC leading for M-biased and FFA leading for P-biased fear faces ($p=0.03$). With increased threat ambiguity, OFC led activity in pSTS later in the trial for both unbiased faces (p=0.005) and for M/P-biased faces (p=0.003), suggesting reflective processing to interpret the meaning of the cue. These results suggest an early role of feedforward processing for parvocellular inputs, evidenced by its flow from V1 and pSTS, and indicate feedback based from magnocellular inputs, as evidenced by its flow from PAC to FFA. Our findings describe the dynamics of information flow for M/P contributions to emotional face perception.

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26.3032 Neurodynamics of reading crowd emotion: Independent visual pathways and hemispheric contributions Hee Yeon Im[1,2](him3@mgh.harvard.edu), Cody Cushing[1], Daniel Albohn[3], Troy Steiner[3], Noreen Ward[1], Reginald Adams, Jr.[3], Kestutis Kveraga[1,2]; [1]Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Charlestown, MA, USA, [2]Department of Radiology, Harvard Medical School, Boston, MA, USA, [3]Department of Psychology, The Pennsylvania State University, State College, PA, USA

Introduction: The visual system exploits redundancies by extracting summary statistics from groups of similar items. In social situations, extracting average emotion from crowds of faces helps us to avoid potential threats (e.g., mob violence or panic). We conducted fMRI, MEG, and behavioral experiments to investigate contributions of magnocellular (M) and parvocellular (P) visual pathways, and of hemispheric lateralization in reading of crowd emotion. Methods: Participants in fMRI (N=32), MEG (N=38), and behavioral (N=36) experiments were presented bilaterally with either arrays of faces or single faces with varying emotional expressions. Participants performed a 2AFC task as to which facial crowd, or single face comparison to avoid. In the behavioral experiment, the original stimuli were converted to M-biased (low-luminance contrast) or P-biased (isoluminant chromatic) stimuli to isolate visual field contributions. Results: fMRI and MEG results revealed that reading crowd emotion evoked highly lateralized activations along the dorsal stream, including the prefrontal and parietal cortex. Conversely, individual emotion processing activated the ventral stream, including the FFA. MEG activity in the precuneus (dorsal stream) differentially increased for facial crowds from 180 ms after stimulus onset, indicating early engagement of M-pathway, whereas the FFA (ventral stream) showed higher activation for individual faces 200 ms after stimulus onset. Furthermore, we found goal-dependent hemispheric asymmetry for crowd emotion processing: the right hemisphere was superior for task-congruent (e.g., angry crowd to avoid) decisions and the left hemisphere for processing task-incongruent cues (e.g., happy crowd). However, the right hemisphere was superior for individual emotion processing regardless of task demands. Finally, in the behavioral task, we found crowd emotion extraction to be more accurate from M- than P-stimuli, and observed goal-dependent hemispheric asymmetry only for M-stimuli. Conclusion: Unlike individual emotion processing, reading crowd emotion is predominantly carried out by the M/dorsal stream, with the right hemisphere superiority for task-congruent decisions.

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26.3033 Spatiotemporal dynamics of view-sensitive and view-invariant face identity processing Charles C.-F. Or[1,2](charlesor@ntu.edu.sg), Joan Liu-Shuang[2], Bruno Rossion[2]; [1]Division of Psychology, School of Humanities & Social Sciences, Nanyang Technological University, Singapore, [2]Psychological Sciences Research Institute & Institute of Neuroscience, University of Louvain, Belgium

The ability to extract the identity of faces across substantial variations in angular head orientation is critical for face recognition, yet the underlying neural mechanism is not well understood. Using a validated paradigm with fast periodic visual stimulation in electroencephalography (EEG; Liu-Shuang, Norcia, & Rossion, 2014, Neuropsychologia), we investigated the tuning function of face identity perception in 20 observers across 7 ranges of viewpoint variations: 0° (no change), ±15°, ±30°, ±45°, ±60°, ±75°, ±90°. In each 60-s stimulation sequence, images of one single face identity, randomly chosen from our stimulus set, were displayed successively at a rapid rate of F = 6 Hz (6 images/s), interleaved with different face identities at fixed intervals of every 7th face (F/7 Hz = 0.86 Hz). Critically, at every stimulation cycle, faces varied randomly both in viewpoint within a predefined range (e.g. in the ±45° condition, faces were shown between -45° and +45° in steps of 5°) and in size between 80% and 120%. Periodic EEG responses at 6 Hz captured general visual processing of the face stimuli, while those at 0.86 Hz and harmonics captured face individualisation. All observers showed significant face individualisation responses, peaking over bilateral occipito-temporal regions. These responses decreased linearly with increasing viewpoint variations (responses decreased by > 50% between 0° and ±90° conditions), suggesting reduced face identity discrimination. Analysing the face individualisation response in the time-domain revealed a dissociation between an early (~200–300 ms) view-sensitive response and a later (~300–600 ms) view-invariant response, both peaking over the same bilateral occipito-temporal regions. These findings suggest two separate view-based face recognition processes, where an initial reduced ability to discriminate face identities due to viewpoint variations is complemented partly by a later, high-level view-invariant process.

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26.3034 The Spatiotemporal Neural Dynamics of the Processing of Infant Faces. Lawrence Symons[1](Larry.Symons@wwu.edu), Kelly Jantzen[1], Amanda Hahn[2], Taylor Kredel[1], Benjamin Ratcliff[1], Nikal Toor[1], McNeel Jantzen[1]; [1]Department of Psychology, Western Washington University, [2]Department of Psychology, Humboldt State University

Substantial evidence indicates that both infant faces and attractive adult faces are associated with stronger activity across an extended face processing networks that critically includes the orbitofrontal cortex and the fusiform gyrus. In this study we used electroencephalography (EEG) to investigate the spatiotemporal brain dynamics of face processing to better understand the degree to which specialized processing occurs for infant faces. EEG was acquired while participants viewed infant faces and adult faces of the same or opposite sex. All faces were digitally manipulated to have high and low aesthetic version. Source analysis of the event related potentials revealed activity across a broad face processing network. The most significant increases occurred for infant faces regardless of cuteness. Early increases were observed at the time of the N170 in the orbitofrontal cortex, the inferior occipital gyrus and the fusiform gyrus. Later increases were observed between 300 and 500 milliseconds in the anterior cingulate, the superior temporal sulcus and the precuneus. Attractiveness resulted in only a modest change in neural activity. The results of this experiment suggest that infant faces undergo specialized processing that does not simply reflect their perceived cuteness.

26.3035 Temporal dynamics of the core and extended face perception system with fMRI Silvia Ubaldi[1](silvia.ubaldi@unitn.it), Aidas Aglinskas[1], Elisa Fait[1], Scott Fairhall[1]; [1]Center for Mind/Brain Sciences, University of Trento

The extensively studied core and extended network for perceiving and knowing about others provides for a critical aspect of human cognition. Here, to gain a systems-level understanding of hierarchical organization and interregional coordination, we apply a novel approach to assess temporal dynamics with fMRI. To determine the differential temporal-tuning of cortical regions, we cognitively overload the system using the rapid-serial presentation of faces (N=35 participants). Famous faces and buildings were presented at twelve different ISIs ranging from 100 to 1200 msec. Contrasting faces with buildings revealed the core system of face perception (OFA, FFA, pSTS), along with the extended system areas (precuneus, mPFC, IFG, ATL, amygdalae). Beta-values for each ISI were extracted to determine differential regional temporal-tuning across the system. Neural activity in OFA and FFA was maximal at ISI 300 msec, offsetting around 400 msec in OFA and at 500 msec in FFA. A similar temporal-tuning profile in IFG is consistent with top-down/perceptual coordination. In extended system areas (precuneus, ATL, mPFC), activity was effectively gated at faster ISI's, coming online only in a second wave of activations peaking at 500 msec. A more complex profile was observed in pSTS. Investigating cortical temporal-tuning provides novel insight into the systems-level organization network. In particular, convergent temporal profiles between IFG and core regions suggest a role of the IFG in top-down amplification of relevant/perceptual signals. We also observed a broad two-stage activation of the system, with early-perceptual processes transitioning to a near simultaneous second wave of activation across the extended system. Interestingly the amygdala, a potentially rapidly activated limbic region, grouped with these latter areas. The application of cognitive-masking to determine regional temporal tuning provides novel insight into the function of face-perception system while simultaneously providing a bridge between fMRI and magneto/encephalographic techniques.

26.3036 Attention modulation of rapid face identity discrimination

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The human face bears prominent biological and social meanings, making it detected quickly and automatically (as early as after 100ms of visual presentation). By contrast, it has been suggested that face identity processing depends on selective attention (Palermo & Rhodes, 2007). Our study used a fast periodic visual stimulation (FPVS) approach to examine the effect of selective attention on face identity discrimination at a glance. We recorded 128-channel EEG while participants viewed 70s sequences of female faces shown at 6 Hz. Within each sequence, a randomly selected identity was repeated (A) with different female face identities (B, C…) embedded every 7th image (AAAAAABAAAAAAC…). Responses at 6 Hz reflect common visual processing of all stimuli, while responses at 0.857 Hz (i.e., 6 Hz/7) reflect face identity discrimination (Liu-Shuang et al., 2014). Participants performed two tasks: (1) on Attend Fixation trials, participants monitored the central fixation cross for color changes (7 targets); (2) on Attend Face trials, participants responded to male faces which randomly replaced a female face identity change (7 targets). Although there were robust face discrimination responses in the orthogonal task as shown previously, attending to face gender increased responses on all electrodes, including the bilateral occipito-temporal regions. This effect does not appear to stem from a general increase in attention as behavioral performance and 6-Hz common visual responses did not differ between conditions. Thus, it appears that selective attention can modulate face identity discrimination in a rapid visual stream, but is not mandatory.

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26.3037 Neural Correlates of Dynamic Face Perception

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Past research on the electrophysiology of face perception has focused almost exclusively on brain responses to artificial stimuli that are transient and static. Therefore, our knowledge of the electrophysiological correlates of face perception is rudimentary, consisting mostly of averaged ERP responses in the first 200 ms after stimulus onset, and lacking virtually any description of how our brain may respond to more naturally occurring dynamic faces. Our goal was to characterize the neural correlates of naturally occurring dynamic faces over a more sustained presentation time (500ms). To this end, we recorded Magnetoencephalography responses to both dynamic and static face and non-face stimuli and used both traditional ERF component analysis to compare our results to the M100 and M170 face responses, as well as machine learning techniques to reveal other representations of viewing a dynamic face. In our ERF analyses, we observe that the dynamic-face induced ERFs have larger M100 and M170 responses (M170 is ~40ms earlier) compared to the static-face ERFs. In our classification analyses, the face vs non-face classification performance is shown to constantly improve as a larger time window is used, until 500ms, yielding ~80% accuracy at 500ms for both dynamic and static stimuli. Hence, the information of face-ness is not specific to a time interval but rather distributed (more widely in the case of dynamic stimuli) in the full temporal content. Finally, this strong face selectivity is achieved at the sensors that probe the temporal lobes for dynamic stimuli, and the occipital lobes for static stimuli. Overall, our results both provide new correlates of dynamic face perception and emphasize the critical information that lies in looking at sustained responses rather than the traditional transient responses to static faces.

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26.3038 Coarse to fine human face detection in a dynamic visual scene

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Human observers detect faces in the visual environment extremely rapidly and automatically. Yet how basic units of visual information processing, i.e. spatial frequencies (SF), play a role in this remarkable ability remains unexplored. We shed light on this fundamental issue by estimating the minimal and optimal amount of SF content required for fast face detection. Stimulation sequences composed of naturalistic and highly variable images of faces and objects were presented with parametrically increasing SF content (0.50 to 128 cycles-per-image or cpi across 14 SF steps, 4 s/step), such that initially blurry images gradually sharpened over the course of a 56-s sequence. Stimuli were shown rapidly at 12 Hz (83-ms SOA), thereby constraining perception to a single glance. A No Face condition consisted of randomly presented object images, while in the critical Face condition, face images were interleaved among objects every 8th image (OOOOOOOFOOOOOOOFOO…) at a frequency of 1.5 Hz (667-ms SOA). Electroencephalographic (EEG) responses at 1.5 Hz (and harmonics) reflect face detection (i.e. differential perception of faces vs. objects) while responses at 12 Hz (and harmonics) reflect visual processing common to objects and faces (Retter & Rossion, 2016, Neuropsychologia). Participants responded the moment they could perceive faces. All 16 participants detected faces at around 6.46 cpi and showed significant face-selective responses located over (right) occipito-temporal regions in the Face condition only. Critically, this face-selective response emerged at around 4.22 cpi (≈1.69 cycles-per-face or cpf) and steadily increased until 23.24 cpi (≈9.30 cpf). Beyond 23.24 cpi, face-selective responses were equivalent to responses to full-spectrum (unfiltered) faces both in amplitude and spatio-temporal dynamics. In summary, neural face detection emerges with extremely coarse SF information (before explicit behavioural response) but continues to integrate SF content until a relatively fine level of image detail, thereby demonstrating the relevance of higher SF in face detection.

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26.3039 Task-modulated integration of facial features in the brain

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The presence of intermodulation frequencies (IM) in an EEG frequency-tagging paradigm indicates non-linear integration of multiple tagged visual features by the brain (Norcia et al., 2015). Despite its growing use in high-level vision, the efficiency of IM as an index of non-linear processing remains unclear, mostly because the importance of the non-linear integration for the task is typically unknown. We assessed the efficiency of IM using a realistic face processing task which we know implements a simple XOR non-linear function—wink detection. On each trial, EEG activity was recorded while each feature of a face flickered at a specific frequency (e.g. left eye: 6 Hz, right eye: 3Hz and mouth: 8 Hz). Subjects had to fixate a central cross and detect winks (one eye closed rather than no eyes/both eyes closed) in the non-linear condition, and the closing of one of the two eyes in the linear condition. Comparisons of brain responses between tasks during identical visual stimulations revealed that left/right-eye tagged IM—the neural response imputable to the non-linear integration of both features—were stronger in occipito-temporal electrodes when this particular feature integration was useful for the task at hand (i.e. wink condition, $F(1,362)=13.98, p< .001$). The magnitude of the eye-pair IM was also associated with faster response time (RT) in the non-linear wink detection condition ($r= -.73, p< .05$), but not in the linear control task ($r=-.10, p>.70$). Oppositely, the magnitude of the mouth tagged neural responses (unrelated to both tasks) was associated with longer RT in both conditions ($r1=.67, p1< .05$; $r2 =.85, p2< .05$), most likely reflecting a distractor effect. While the magnitude of feature frequency-tags clearly outweighed that of IM (average SNR were ~15 and ~1.75, respectively), the present results clearly demonstrates that IM can be an effective neural correlate of non-linear visual integration processing.

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Saturday PM

26.3040 **Characteristics of face adaptation revealed by EEG** Owen Gwinn[1](ogwinn@unr.edu), Talia Retter[1,2], Sean O'Neil[1], Michael Webster[1]; [1]Department of Psychology, Center for Integrative Neuroscience, University of Nevada, Reno, USA, [2]Psychological Sciences Research Institute, Institute of Neuroscience, University of Louvain, Belgium

Recent work has demonstrated robust face adaptation in neural responses monitored with electroencephalography and frequency tagging (Retter & Rossion, 2016). We examined factors controlling this adaptation and whether they exhibit similar properties to the face aftereffects measured behaviorally. An average female face was contracted or expanded along the horizontal or vertical axis to form four images. Observers viewed a 20-sec sequence of the faces presented at a rate of 6 Hz, while responses were recorded with high-density EEG. This resulted in a 6 Hz signal over occipital channels, indicating that responses to each of the four distortions were equal. This sequence was repeated after 20-sec adaptation to alternations between two of the faces (e.g. horizontal contracted and expanded), with the logic that a selective response change to the adapting faces should lead to asymmetric responses during the test phase and a signal at 3 Hz. This pair has the same mean (undistorted) as the test sequence and thus should not bias responses driven only by the mean. However, adaptation instead produced a 3 Hz response that was present over right occipito-temporal sites, consistent with selective adaptation to the distortion axis. Similar biases were found when the adapting distortions were twice the magnitude of test distortions, or when adapting to a single novel distortion (e.g. expanded both horizontal and vertical) that was not part of the test sequence. These effects argue against the alternative that the neural responses are driven by prior exposure to the same image or face during adaptation and test. Instead, the neural aftereffects appear to reflect response changes induced by both the mean distortion and the contrast (variance) of the distortions. While adaptation to the mean parallels perception, the neural adaptation to variance appears stronger and may reflect processes distinct from those underlying the perceived aftereffects.

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26.3041 **Representational confusion: the possible consequence of demeaning your data** Fernando Ramírez[1,2](fernando.ramirez@bccn-berlin.de), Carsten Allefeld[1,2], John-Dylan Haynes[1,2]; [1]Bernstein Center for Computational Neuroscience Berlin, Charité – Universitätsmedizin Berlin, Germany, [2]Berlin Center for Advanced Neuroimaging, Charité – Universitätsmedizin, Berlin, Germany

The increased sensitivity afforded by multivariate pattern analysis methods (MVPA) has led to their widespread application in neuroscience. Recently, similarity-based multivariate methods seeking not only to detect information regarding a dimension of interest, say, an object's rotational angle, but to describe the underlying representational structure, have flourished under the name of Representational Similarity Analysis (RSA). However, data pre-processing steps implemented before conducting RSA can significantly change the correlation (and covariance) structure of the data, hence possibly leading to representational confusion—i.e., concluding that brain area X encodes information according to representational scheme A, and not B, when the opposite is true. Here, we demonstrate with computer simulations and empirical fMRI-data that time series demeaning (including z-scoring) can lead to representational confusion. Further, we expose a complex interaction between the effects of data demeaning and how the brain happens to encode information—usually the question under study—hence incurring a form of circularity. These findings should foster reflection on implicit assumptions bearing on the interpretation of MVPA and RSA, and awareness of the possible impact of data demeaning on inferences regarding representational structure and neural coding

26.3042 **Representational similarity analysis of EEG and fMRI responses to face identities and emotional expressions** Kaisu Ölander[1,2](kaisu.olander@helsinki.fi), Ilkka Muukkonen[1], Jussi Numminen[3], Viljami Salmela[1,2]; [1]Department of Psychology and Logopedics, University of Helsinki, Helsinki, Finland, [2]Aalto NeuroImaging, Aalto University, Espoo, Finland., [3]Helsinki Medical Imaging Center, Töölö Hospital, University of Helsinki, Helsinki, Finland

Currently it is acknowledged that the cortical network processing facial information consists of several areas that process different aspects of faces from low-level features to person-related knowledge. We applied multivariate representational similarity analysis to investigate how parametric variation of facial expressions and identities affect temporal (EEG) and spatial (fMRI) patterns of brain activity. As stimuli, we used faces with neutral expression, happy, fearful, angry, and morphed (50%) versions of the expressions, as well as four core identities (two male and two female) and all combinations of these identities morphed (33 and 67%) to each other. In total, we had 112 different faces (7 expressions from 16 identities). The representational dissimilarity matrices (RDMs) were calculated for each time point in the event related potentials (ERPs) from EEG, and for each voxel in fMRI data by using a searchlight approach. Low-level stimulus model RDMs were based on spatial frequency (SF) spectrum of the whole face, the region around the eyes or the region around the mouth. Additional model RDMs were based on the emotional expressions, identities, and interactions between these factors. ERP RDMs correlated with SF models between 220-460 ms, with the identity model between 270-420 ms and 670-1000 ms, and with emotion models at 180 ms, between 230-500 ms, and at 600 ms. There was also an interaction between emotion type and identity. In fMRI, activity patterns related to expressions were found in early visual areas (V1-V3), lateral occipital complex (LOC), occipital face area (OFA), fusiform face area (FFA), posterior superior temporal sulcus (pSTS), and left middle frontal regions, and identity related patterns only in frontal areas. Distinct distributions of positive and negative correlations across face selective areas suggest a different type of processing in LOC, OFA and FFA in comparison to other regions in the face network.

Acknowledgement: Academy of Finland

EYE MOVEMENTS: PURSUIT AND ANTICIPATION

Saturday, May 20, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

26.3043 **Does the baseline motor response predict the short-term adaptability of phasic vergence?** Ian Erkelens[1](ierkelen@uwaterloo.ca), William Bobier[1]; [1]University of Waterloo, Optometry & Vision Science

It has been hypothesized that faster, more accurate baseline neural-motor responses result in greater adaptability to repeated external perturbations. Like saccades, phasic convergence exhibits robust adaptive behavior when exposed to double-step gap stimuli. Directional asymmetries exist in the non-adapted baseline motor response of this phasic vergence mechanism to convergent or divergent disparities. We leverage these directional asymmetries to investigate the relationship between the baseline motor response and its adaptability to a double-step convergent or divergent stimuli. 10 adults (26±3.8y/o) completed 2 study visits where baseline convergence or divergence responses to a 2° disparity step were measured and then adapted using an increasing double-step stimuli (2°+1.5°, 175ms). Individual eye movements were recorded at 250Hz with infrared video oculography, while stimuli where presented dichoptically at 40cm. Vergence kinematics of baseline and adapted responses were compared between stimulus directions. Compared to convergence, divergence exhibited significantly less adaptive changes in gain (9±2%, vs. 31±3% p=0.0005), peak velocity (4±4% vs. 32±3% p=0.0001) and peak acceleration (3±5% vs.30±6%, p = 0.006). Only divergence gain was altered after adaptation (p = 0.005); while divergence peak velocity (p = 0.36) and peak acceleration (p=0.63) were unchanged. Adapted divergence response duration increased (25±9ms, p=0.03), whereas adapted convergence duration was unchanged (-6±9ms, p=0.97). Baseline convergence peak velocity was faster (12.5±1.4°/s vs. 8.7±2.4°/s, p=0.004) than divergence in all subjects. Baseline vergence peak velocity was the strongest predictor of the adaptability of the gain and peak velocity of each system. The results demonstrate that phasic convergence adapts to systematic errors by altering all orders of the dynamic response, whereas phasic divergence adapts by altering only the duration of response output. This adaptive behavior is most strongly correlated with the initial peak velocity of the response, suggesting the baseline neural-motor function determines the degree of adaptability within this oculomotor system.

Acknowledgement: NSERC, OGS, COETF

26.3044 **Dynamic modulation of volatility by reward contingencies: effects on anticipatory smooth eye movement** Jean-Bernard Damasse[1](jean-bernard.damasse@univ-amu.fr), Anna Montagnini[1], Laurent Perrinet[1]; [1]Institut de Neurosciences de la Timone, CNRS - Aix-Marseille Université, Marseille, France

By using a visual tracking task, where we manipulated the probability for the target to move in a direction (Right) or another (Left) in three different direction-biased blocks (with 50%, 75% and 90% of rightward trials respectively), we observed a systematic and graded anticipatory smooth pursuit eye movements (aSPEM) in human volunteers, suggesting that probabilistic information about the a priori direction of future motions is inferred to optimize visuomotor tracking. Smooth eye movements are known to be sensitive to reward contingencies both during the visually guided phase (Schütz et al, 2015), maintained pursuit during blanking (Madelain & Krauzlis, 2003) and anticipation, where aSPEM could be enhanced or reduced by reward in a velocity criterion-matching protocol (Damasse et al, 2016). Optimal decision-making results from the weight given to the outcomes of possible decisions. These weights reflect their relevance in predicting future outcomes, which itself is related to the volatility of the environment (Behrens et al, 2007). In our situation, indeed, the way each past outcome is included to infer decision-making in the present is quite complex, as it has to account both for an evolving reward schedule and on sensorimotor regularities (probability of motion direction). To analyze this, we implemented an agent that produces aSPEM velocities and parameterized by a characteristic memory decay time (i.e. the number of past trials used to estimate the likelihood of a particular motion direction –similarly to Anderson & Carpenter, 2006). We challenged this model by comparing its predictions to the experimental aSPEM velocity changes associated to specific trial-sequences (tested across many subjects). Results suggest that aSPEM reflect an estimation of the volatility of predictive information that may be dynamically biased by the reinforcement program. This dynamical bias was consistent with our previously reported block-based results.

Acknowledgement: ANR grant « Reinforcement and Eye Movements » ANR-13-APPR-0008-02

26.3045 Effect of attention on cyclovergence and cycloversion eye movements.

Madhumitha Mahadevan[1](MMahadevan@Central.UH.EDU), Scott Stevenson[1]; [1]College of Optometry,University of Houston

This study aimed to determine the effect of spatial attention on torsional eye responses. Verbal instructions were used to ask the subjects to pay attention to one of two torsion stimuli to determine if the instructions had any effect on cyclovergence and cycloversion response amplitudes. The stimuli consisted of a fixation dot, an inner disk, and an outer annulus, each filled with static random dots. Diameters of the fixation dot, the central disk and the annulus were 0.5 degrees, 40.3 degrees and 80.6 degrees respectively. Dots in the central disk and annulus rotated 5 degrees back and forth about the central fixation with a frequency of 0.25 or 0.5 Hz. Four conditions were run to balance attention and frequency across field position. Dots seen by left and right eyes rotated in the same (cycloversion) or opposite (cyclovergence) directions. Subjects (N = 6) wore red – green anaglyph glasses and were asked to hold their head and gaze steady on the central fixation dot and pay attention to the torsion motion of the disk and ignore the annulus or vice versa. Scleral search coils were used to record eye position at 500 Hz. Fourier analysis was used to determine the tracking amplitude at each frequency for each condition. We observed consistent responses to both vergence and version stimuli in all subjects for both frequencies, with an overall average tracking gain of 0.08. Instruction to attend or ignore made a roughly 2x change in version responses in 3 subjects, a 1.25 change in a 4th subject and no change in a 5th and 6th subject. No subject showed a change in cyclovergence responses with attention. The results of this study suggest that the mechanisms controlling cyclovergence are outside the influence of attentional enhancement.

Acknowledgement: Student Vision Science Grants to advance Research (SVGR) - University of Houston, College of Optometry

26.3046 Cognitive expectation modulates ocular torsion

Austin Rothwell[1](austinrothwell222@gmail.com), Miriam Spering[1,2,3]; [1]Ophthalmology & Visual Sciences, University of British Columbia, [2]Institute for Computing, Information & Cognitive Systems, University of British Columbia, [3]Center for Brain Health, University of British Columbia

Purpose: Torsional eye movements are considered reflexive responses to visual image rotation or to head roll about the visual axis. Recent studies indicate that torsion scales with visual stimulus properties such as rotational direction, speed and size, indicating a voluntary component. However, it is unclear whether these eye movements can be modulated by cognitive factors such as expectation. Method: Head-fixed healthy human adults (n=6) viewed a textured disk, translating horizontally to the right across a computer monitor and rotating about its center. This type of stimulus triggers horizontal smooth pursuit eye movements with a torsional component. Stimulus rotation was either clockwise, in the same direction as a rolling ball ("natural"), or counterclockwise ("unnatural"). In baseline trials, the texture moved horizontally without rotation. These three rotation conditions were presented in separate blocks of 100 trials each, two blocks per condition, to elicit cognitive expectation of rotational direction. Three-dimensional eye position was recorded with a head-mounted Chronos eye tracker. Results: Observers initiated horizontal pursuit 250 ms prior to stimulus onset in anticipation of translational stimulus motion. This effect was stronger for baseline than for rotation conditions, indicating that stimulus rotation is taken into account when computing anticipatory horizontal pursuit velocity. Interestingly, the eyes also started rotating clockwise in response to "natural" and counterclockwise in response to "unnatural" rotation prior to stimulus onset in anticipation of stimulus rotation. Conclusions: Torsional eye movements can be modulated by cognitive factors, indicating a strong voluntary component in the control of these movements. The frontal pursuit pathway, including areas such as the frontal eye field, might carry ocular torsion signals and underlie the effects of cognitive expectation on ocular torsion.

26.3047 Altered smooth pursuit of global motion caused by illusory positon shifts in local elements

Zheng Ma[1](zma@ski.org), Steve Heinen[1]; [1]The Smith Kettlewell Eye Research Institute

Previously we showed that the pursuit system can integrate local motion information to veridically pursue the global motion of a large object. Here, we demonstrate that illusory position shifts in local elements alter pursuit gain for global motion, and similarly affect global motion perception. The target consisted of four Gabor patches arranged in a diamond configuration, each drifting within a circular aperture. It is well known that Gabors drifting within static apertures produce an illusory displacement of the Gabor in the drift direction. In the current experiment, the apertures containing the Gabor patches translated together to the left or right in each trial at a constant velocity of 10°/s. Drift direction conditions relative to the global translation direction were Same, Opposite, or Orthogonal. Observers were instructed to pursue the global motion. Pursuit gain was higher in the Same than the Opposite condition, evidence that the local drifting motion patches disrupted the pursuit system's ability to integrate global motion. To test if the effect originated in the motion perception system, we assessed observers' perceived speed of the translating stimuli using a staircase method. Consistent with the pursuit result, we found higher global speed perception in the Same than in the Opposite condition. We further asked if integration could be restored when a non-illusory local motion cue was provided by adding circular frames to each Gabor patch. This manipulation reduced the difference between the Same and Opposite conditions for both smooth pursuit and perception. The results suggest that local moving elements that produce an illusory position shift can interfere with the pursuit and perception of global motion. However, when additional local translation cues are provided, motion information is successfully integrated to accurately guide pursuit and perception.

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26.3048 Response of pursuit cells in MST after eye position perturbation by microstimulation of the Superior Colliculus (SC)

Jérome Fleuriet[1,2](fleuriet@uw.edu), Leah Bakst[2,3], Michael Mustari[1,2,4]; [1]Department of Ophthalmology, University of Washington, Seattle, WA, [2]Washington National Primate Research Center, University of Washington, Seattle, WA, [3]Graduate Program in Neuroscience, University of Washington, Seattle, WA, [4]Department of Biological Structure, University of Washington, Seattle, WA

Primates use the fovea to maintain high quality central vision of the world. When a target is moving, smooth pursuit eye movements (SEM) keep the fovea of both eyes on target. A large proportion of neurons in area MST discharge during SEM. These smooth pursuit cells (SPC) carry visual and extraretinal signals. We recorded 27 SPC in MST of a macaque monkey during SEM trials interrupted with a saccade that was elicited by electrical microstimulation (MS) in the SC. The MS consisted of a train of pulses (0.1ms, 400Hz, 40ms) at low currents (< 40mA). The tracking behavior was characterized by 1) an evoked saccade that brought the eye outside the tar-

Saturday PM

get path, 2) a SEM following this abrupt change in eye position and 3) a corrective saccade. We quantified the ratio of activity after the evoked saccade, before the corrective saccade and during the corrective saccade. A majority of neurons (63%) presented ratios between 0.8 and 1.2 after the evoked saccade but ratios less than 0.8 during the corrective saccade. Among this subpopulation, 59% actually had a decrease of their firing rate before the corrective saccade. On average, this drop of activity occurred 54 (±11ms) after the evoked saccade offset or 109 (±9ms) after its onset. Interestingly, in 90% of cases the latency of this drop of activity was sensitive to the delay between the evoked and corrective saccades. Finally, 22% neurons did not present a drop of activity during these intervals while 15% presented a decrease from the evoked saccade offset. This eye position perturbation showed that the activity of a majority of MST smooth pursuit cells was not interrupted by a direct corollary discharge from the saccadic system. However this activity seems inhibited by the occurrence of a corrective saccade even though not always time-locked to it.

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26.3049 **Eye-hand coordination during visuomotor tracking under complex hand-cursor mapping** Frederic Danion[1](frederic.danion@univ-amu.fr), Randy Flanagan[2]; [1]Institut de Neurosciences de la Timone, CNRS, Aix-Marseille University, , [2]Centre for Neuroscience Studies and Department of Psychology, Queen's University

Previous studies have investigated eye-hand coordination when tracking with the hand a pseudo-random target (Xia & Barnes, 1999; Soechting et al, 2010; Tramper & Gielen, 2011). In all these studies the mapping between hand motion and cursor motion was always straightforward. Here we investigate the impact of using a complex hand-cursor mapping. Two hand-cursor mappings were tested, either a simple one in which hand and cursor motion matched perfectly, or a complex one in which the cursor behaved as a mass attached to the hand by means a spring. Pseudo-random target motion was obtained via the combination of two sinusoids on each of the vertical and horizontal axis (Mrotek & Soechting, 2007). Subjects were instructed to move their hand so as to bring the animated cursor as close as possible from the moving target. Our results showed that hand tracking performance was substantially more accurate under the regular mapping that the spring one. On average the tracking error (i.e. cursor-target distance) was almost two times greater under the spring mapping (4.8 vs. 2.7cm). Although in the latter case hand tracking improved across trials, performance never returned to baseline (i.e. compared to regular). Despite those substantial differences in hand tracking performance, eye behaviour seemed relatively unaffected. Indeed under both types of mapping, gaze always led cursor position and lagged on target position, but with gaze remaining substantially closer from the target (about 2.5 cm) than from the cursor (up to 4.5 cm under spring). In addition, we found no difference in the saccade rate between the two mappings. Overall we conclude that 1) even when subjects have to learn a complex hand-cursor mapping, gaze is mostly driven to gather information about ongoing target motion, and 2) eye behaviour is relatively insensitive to hand-cursor mapping.

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Object Recognition: Where in the brain?

Saturday, May 20, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4001 **Lateral occipitotemporal cortex's selectivity to small artifacts reflects multi-modal representation of shape-grasp mapping elements** Wei Wu[1](wuwei7cool@gmail.com), Xiaoying Wang[1], Chenxi He[1], Yanchao Bi[1]; [1]State Key Laboratory of Cognitive Neuroscience and Learning & IDG/McGovern Institute for Brain Research, Beijing Normal University

Recent studies have reported intriguingly similar activation preference to small artifacts relative to other object categories in the left lateral occipitotemporal cortex (lLOTC) across various modality and populations (see reviews in Riciardi et al., 2014; Bi et al., 2016). What drives the multimodal tool selectivity here is unclear. Our study investigated the potential properties underlying the multimodal small artifact selectivity in the lLOTC using representational similarity analysis (RSA). BOLD-fMRI responses to 33 small artifacts were collected for both sighted and congenitally blind individuals when they performing size judgment tasks on object auditory names or pictures. Similarity ratings on the overall shape, the shape of the object parts people typically interact with (i.e., when grasping for typical use), the manner of manipulating and of grasping were collected to build 4 different behavioral representational similarity matrices (RSMs). RSA identified significant correlation between functionally-defined lLOTC's neural RSM and the grasping-manner and grasp-part-shape RSMs across all experiments (Rs > 0.109; ps < 0.012). Furthermore, the shared variance of these two variables derived from principal component analyses significantly correlated with lLOTC's neural RSM across all experiments (sighted auditory: r = 0.129, P < 0.01; sighted visual: r = 0.215, P < 10-6; blind: r = 0.124, P < 0.01). The unique effects of either of these two variables, as well as the effects of overall-shape and overall-manipulation manner, were observed in the sighted visual experiment and not the blind auditory experiment(Rs < 0.07; ps > 0.127), i.e., not exhibiting multi-modal patterns. These results indicate that the representation of the shape element that is indicative of the manner of grasping best explains the multi-modal representation of small artifacts in lLOTC, highlighting the critical role of interaction between visual and nonvisual object properties on the functional organization of the higher-order visual cortex (Bi et al., 2016).

26.4002 **The N300p, a novel ERP component associated with extended categorization training** Yue Meng[1](mengyue0903@gmail.com), Shamsi Monfared[1], Jonathan Folstein[1]; [1]Florida State University

Subordinate level category learning, which is thought to elicit perceptual expertise, affects allocation of attention to learned stimuli and creation of new perceptual and mnemonic representations. There is some controversy concerning whether effects of expertise are driven primarily by attention or formation of new perceptual representations (e.g. recruitment of the FFA). It is therefore desirable to study the neural correlates of category learning in the context of an attention manipulation. Interestingly, the N250, an ERP component associated with perceptual expertise, has a similar time course and postero-lateral scalp distribution to an attention-related ERP component, the selection negativity. Here we attempted to replicate and extend a previous study in which we found evidence dissociating the N250, which was sensitive to trained vs. untrained stimuli, from the selection negativity, which was sensitive to number of features shared with a rare target. Participants were trained over six sessions (an increase from our previous study) to categorize cartoon alien stimuli, followed by an EEG session during which participants detected single target alien and ignored non-targets that shared between zero and four features with the target. This task was performed on trained vs. untrained stimuli appearing at fast or slow presentations rates (an attempt to manipulate attentional load). The selection negativity scaled with the number of target features in the stimulus, but was insensitive presentation rate. The comparison of trained to untrained stimuli elicited an unexpected new component, which we call the N300p. This large negative component had a similar time course to the N250 but, unlike the N250, a clearly parietal scalp distribution. The N300p could be a new expertise component associated with novel aspects of our task, which included many-to-one mapping and a stimulus set in which participants were required to process disjunctions of highly interchangeable features.

26.4003 **A-modal versus Cross-modal: How input modality and visual experience affect categorical representation in the "visual" cortex** Stefania Mattioni[1,2](stefania.mattioni@unitn.it), Mohamed Rezk[2], Karen Cuculiza[1], Ceren Battal[1], Roberto Bottini[1], Markus Van Ackeren[1], Nick Oosterhof[1], Olivier Collignon[1,2]; [1]Center for Mind/Brain Sciences (CIMEC), University of Trento, Italy, [2]Institute of Psychology (IPSY) and Institute of Neuroscience (IONS), University of Louvain-la-Neuve, Belgium

It has recently been proposed that some regions of the occipital cortex, typically considered purely visual, develop a preferential tuning for specific categories independently of the sensory input and visual experience. In contrast, several studies showed that occipital responses to non-visual inputs is unique to blind individuals due to crossmodal plasticity. To further assess how the functional tuning of occipital regions is (in)dependent of visual input and experience, we characterized with fMRI brain responses to 8 categories presented acoustically in sighted and early blind individuals, and to the same stimuli presented visually in a separate sighted group. First, we observed that the posterior middle temporal gyrus (pMTG) was

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the most reliable region being able to decode the 8 presented categories independently of the input modality (in vision and audition in the sighted) and visual experience (in audition in the sighted and blind). Importantly, we also observed that the occipital cortex of blind individuals showed enhanced coding of acoustical stimuli. To further understand the nature of this reorganization, we used representational similarity analysis (RSA) in those regions in order to link similarities of brain activity patterns with different features similarities of the acoustical stimuli space. We found a stronger correlation between the patterns of activity in some portions of the occipital cortex with the categorical features of the stimuli (e.g. animate-inanimate), whereas we did not find any information about the physical properties (e.g. pitch) of the stimuli. Together, our results suggest that the occipital cortex shows a strong sensory tuning toward visual stimuli in the sighted and reorganizes to enhance its response toward non-visual input in case of early visual deprivation. Additional analyses on the nature of the functional reorganization show that the representation is mostly linked to "high-level" categorical tuning rather than low-level properties of the sounds (e.g. pitch).

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26.4004 **Contralateral bias persists in category-selective visual areas** Sarah Herald[1](sarah.b.herald.gr@dartmouth.edu), Hua Yang[2], Bradley Duchaine[1]; [1]Psychological and Brain Sciences, Dartmouth College, [2]University of Massachusetts Medical School, Worcester, MA

fMRI studies in humans and single-unit work in macaques has suggested that visual recognition mechanisms show contralateral biases that are much weaker than those found in early visual cortex (Hemond et al., 2007). In almost all these studies, single stimuli were displayed peripherally to assess biases. In natural vision though, visual stimuli are present in both hemifields, and a recent ERP study found the N170 was driven exclusively by the contralateral stimulus when faces and houses were simultaneously presented to both hemifields (Towler & Eimer, 2015). To examine contralateral biases in category-selective visual areas using a more naturalistic display with fMRI, we first carried out a dynamic localizer using videos of faces, bodies, scenes, objects, and scrambled objects to identify category-selective areas. We then scanned participants while they viewed faces and houses simultaneously presented to the left and right visual hemifields. We found that face-selective and place-selective areas displayed large contralateral biases in which category-selective regions were primarily influenced by contralaterally-presented stimuli. For example, in the right OFA, the response to a contralateral house and an ipsilateral face is comparable to a contralateral house and ipsilateral house. Conversely, the response to a contralateral face and an ipsilateral house is only slightly weaker than the response to a contralateral face and ipsilateral face. Other category-selective areas, though not all, showed responses that were much more strongly modulated by contralateral than ipsilateral stimuli. These findings tentatively suggest that, under natural viewing conditions, peripheral stimuli are represented primarily in contralateral category-selective areas and that detection of peripheral stimuli is carried out largely by the contralateral hemisphere.

26.4005 **Building of object view invariance in a newly-discovered network in inferior temporal cortex** Pinglei Bao[1,2](pbao@caltech.edu), Doris Tsao[1,2]; [1]Division of Biology and Biological Engineering, Caltech, [2]The Howard Huges Medical Insitute

Object recognition in primates is mediated by hierarchical, multi-stage processing of visual information within occipital and inferior temporal (IT) cortex. It is known that IT contains several networks that process specific categories or stimulus dimensions. Furthermore, at least in the case of face processing network, the nodes appear to be organized hierarchically, e.g., neurons in the middle faces patches are tuned for specific facial views, while those in the most anterior patch are tuned for the identity of faces in a view-invariant way. However, there remains a fair amount of IT cortex that doesn't belong to any known network, raising the question: are there any new, undiscovered networks not yet accounted for by existing functional parcellation studies? If so, what are these networks processing and how are they organized? To address this question, we exploited the technique of electrical microstimulation combined with simultaneous functional magnetic resonance imaging. Electrical microstimulation of a region of macaque IT cortex not belonging to any known network produced strong activation in three patches that also didn't overlap with any known networks. We targeted single-unit recordings to these three patches, while monkeys passively viewed an image set consisting of 51 objects with 24 views for each object; the objects included faces, animals, houses, vegifruit, vehicle, and man-made objects. Average responses across neurons from the three patches revealed high similarity in object preferences between the patches, further confirming these patches belong to a common network; for example, all three patches showed the smallest response to faces. Representational similarity analysis on population single-unit responses in each of the three patches revealed the most view-invariant representation in the most anterior patch, and the least view-invariant representation in the posterior patch, suggesting that, analogous to the face patch network, view-invariant object representation is built up hierarchically within this new network.

26.4006 **Decoding the representational dynamics of object recognition with MEG, behavior, and computational models** Brett Bankson[1](brett.bankson@nih.gov), Martin Hebart[1], Chris Baker[1]; [1]Section on Learning and Plasticity, Laboratory of Brain and Cognition, National Institute of Mental Health

Previous studies using electrophysiological recordings have identified the time course of category representation during the first several hundred milliseconds of object recognition, but less is known about the perceptual and semantic features reflected by this information (Cichy et al., 2016, Clarke et al., 2012). Here we apply machine learning methods and representational similarity analysis (RSA) to MEG recordings in order to elucidate the temporal evolution of representations for concrete visual objects. During MEG recording, 32 participants were repeatedly presented with object stimuli while completing a visual oddball task. Half of the participants were exposed to one set of 84 object exemplars, while the other half was presented with different exemplars of the same concepts. The 84 object concepts were selected based on lexical frequency. We used a support vector classifier to produce pairwise decoding accuracies between all object items at all time points, which served as dissimilarity matrices for later analyses. Complementary behavioral data from an object arrangement task were included in our analyses, as well as model predictions from a semantic model and a convolutional neural network. MEG analyses showed robust pairwise decoding of object images, peaking around 100 ms post-stimulus onset. Before 150 ms, the MEG data contained information similar to the the early layers of a convolutional neural network (CNN), suggesting early discriminability in patterns of neural activity based on visual information before 150 ms. From 200-450 ms, the MEG data show persistent similarity across visual exemplars for the same concept. Further, there was high correlation with the behavioral data, mid-level CNN layers, and the semantic model. Together, these results suggest the emergence of an abstract behaviorally-relevant representation of concrete object concepts peaking between 250-300 ms.

26.4007 **Representation of visual and motor object features in human cortex** Ariana Familiar[1](afam@sas.upenn.edu), Heath Matheson[1], Sharon Thompson-Schill[1]; [1]Department of Psychology, University of Pennsylvania

To accomplish object recognition, we must remember the shared sensorimotor features of thousands of objects, as well as each object's unique combination of features. While theories differ on how exactly the brain does this, many agree that featural information is integrated in at least one cortical region, or "convergence zone", which acts as a semantic representation area that links object features of different information types. Moreover, it has been posited the anterior temporal lobe (ATL) acts as a "hub" that associates object features across sensory and motor modalities, as it is reciprocally connected to early modality-specific cortical regions and patients with ATL damage have shown deficits in processing and remembering object information across input modalities (Patterson et al., 2007). Our lab recently found evidence that the left ATL encodes integrated shape and color information for objects uniquely defined by these features (fruits/vegetables; Coutanche & Thompson-Schill, 2014), suggesting ATL acts as a convergence zone for these visual object features. However, whether ATL encodes integrated object features from different modalities had not been established. We used functional magnetic resonance imaging (fMRI) and multi-voxel pattern analysis (MVPA) to examine whether ATL acts as an area of convergence for object features across visual and motor modalities. Using a whole-brain searchlight analysis, we found activity patterns during a memory retrieval task in a region within the left ATL could successfully classify objects defined by unique combinations of visual (material) and motor (grip) features, but could not classify either constituent feature while generalizing over identity. These results suggest that in addition to being a convergence zone for visual object features, left ATL also acts as an area of convergence for object information across visual and motor modalities.

26.4008 The large-scale organization of object processing in the ventral and dorsal pathways

Erez Freud[1,2](erezfreud@gmail.com), Jody Culham[3,4], David Plaut[1,2], Marlene Behrmann[1,2]; [1]Department of Psychology, Carnegie Mellon University, [2]Center for the Neural Basis of Cognition, Carnegie Mellon University and the University of Pittsburgh , [3]The Brain and Mind Institute,University of Western Ontario, [4]Department of Psychology,University of Western Ontario

One of the hallmark properties of the ventral visual pathway is sensitivity to object shape. Accumulating evidence, however, suggests that object-based representations are also derived by the dorsal visual pathway although less is known about the characteristics of these representations, their spatial distribution, and their perceptual importance. To bridge this gap, the present study combined psychophysical and fMRI experiments in which participants viewed and recognized objects with different levels of scrambling that distorted object shape. Neural shape sensitivity was assessed by measuring the reduction of fMRI activation in response to scrambled versus intact versions of the same stimulus. In the ventral pathway, shape sensitivity increased linearly along an anterior-posterior axis from early visual cortices (i.e., v1-v4) to posterior extrastriate cortices (i.e., LO1) and remained constant along the occipitotemporal cortex. In the dorsal pathway, shape sensitivity also increased linearly along an anterior-posterior axis from early visual cortices (i.e., v1-v3d) to posterior extrastriate cortices (i.e., V3a, posterior IPS). However, in stark contrast to the ventral stream, in moving from posterior extrastriate cortices to more anterior regions (i.e., IPS 1-4, aIPS), shape selectivity gradually decreased. Interestingly, as with the anterior ventral pathway, the posterior IPS activation profile was found to be highly correlated with recognition performance obtained outside of the scanner, further pointing to a plausible contribution of this region to perception. Finally, these results were replicated using a different method for manipulating object integrity (diffeomorphic alteration) suggesting the results are not attributable to modulations of low-level object features. Together, these results provide novel evidence that object representations along the dorsal pathway are not monolithic and gradually change along the posterior-anterior axis. These findings challenge the binary dichotomy between the two pathways and suggest that object recognition might be the product of more distributed neural mechanisms.

26.4009 Effect of Task on Object Category Representations Across Human Ventral, Dorsal, and Frontal Brain Regions

JohnMark Taylor[1](johnmarktaylor@g.harvard.edu), Maryam Vaziri-Pashkam[1], Yaoda Xu[1]; [1]Department of Psychology, Harvard University

Recent evidence demonstrates that dorsal visual stream regions represent not just "where" or "how" information, but also object identity ("what") information like the ventral stream. Here, we further explored the hypothesis that the dorsal stream encodes object representations in a manner that also reflects task demands, whereas the ventral stream encodes objects in a relatively task-invariant manner. We also examined responses in a frontal ROI corresponding to the frontal eye field (FEF), as it belongs to the dorsal attention network along with the intraparietal sulcus (IPS), and since frontal regions also participate in object categorization tasks. In our fMRI MVPA study, participants viewed blocks of pictures from 8 object categories and did either a category oddball task (e.g., respond to a face in a block of houses) or a one-back task (e.g., respond to the same face appearing twice in a row). The oddball task thus drew participants' explicit attention to object category while the one-back task drew attention to the exact exemplar shown. We examined object category representations across a number of ROIs, including object responsive regions in lateral occipital cortex, inferior and superior IPS, and FEF. Consistent with past research, we obtained significant object category decoding across both visual pathways, and additionally in FEF. Category decoding was not enhanced by the category oddball task, suggesting that information extracted in the one-back task was sufficient to distinguish categories. We found that task and category contributed roughly equally to the category representational structures in the dorsal and frontal ROIs, but in ventral regions category contributed much more than task to the category representational structures. Task context thus plays a more prominent role in shaping object category representation in dorsal and frontal regions than in ventral regions. Supported by NIH grant 1R01EY022355 to YX

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26.4010 Spatial frequency tolerant object representations in the ventral and dorsal visual processing pathways

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Object category representations have been found in both human ventral and dorsal visual processing regions. Given the differences in anatomical connections to parvo- and magno-cellular layers in LGN, the two pathways may exhibit differential sensitivity to spatial frequency. To test this idea, in this study, observers viewed blocks of images from six natural object categories and performed a one-back repetition detection task on the images. Images were shown in full spectrum, high spatial frequencies (>7 cpd), or low spatial frequencies (< 1 cpd). Using fMRI and MVPA, we examined how object category decoding would be modulated by the spatial frequency content of the images. We examined responses from topographic regions V1-V4 and IPS0-2, the object shape selective lateral occipital cortex (LO), a temporal region activated by our object stimuli, as well as superior and inferior IPS (two parietal regions previously implicated in object processing). We obtained above chance category decoding for the intact, high and low frequency images in all the regions examined. Importantly, the decoding accuracy was no different between the high and low frequency images in all the regions examined except for V4 and IPS2 where decoding was higher for the high frequency images. We also trained the classifier with high and tested it with low frequency images or vice versa and found that all regions showed robust generalization across spatial frequency. A representational similarity analysis further showed that object category representations were separated based on spatial frequency in early visual but not in dorsal and higher ventral regions. These results demonstrate that object category representations in both ventral and dorsal regions are tolerant to changes in spatial frequency and argue against a dissociation of the two pathways based on spatial frequency sensitivity.

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26.4011 Encoding of partially occluded and occluding stimuli in the macaque inferior temporal cortex

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Image segmentation – the process by which scenes are segmented into component objects – is a fundamental aspect of vision and a cornerstone of scene understanding; its neural basis, however, is largely unknown. Partial occlusions pose a special challenge to segmentation because, unlike non-overlapping stimuli, they require the parsing of overlapping contours and regions and/or the grouping of noncontiguous regions. To begin to understand how partially occluded stimuli are segmented in the primate brain, we studied the responses of single neurons in IT cortex to shape stimuli subjected to increasing levels of occlusion. We asked whether IT responses are consistent with a segmented representation whereby responses of each neuron are dictated by either the occluded or the occluding stimulus, but not both. We recorded from 43 well-isolated, single IT neurons as animals were engaged on a sequential shape discrimination task. On each trial, two stimuli were presented in sequence and the animal had to report whether the stimuli were the same or different with a rightward or leftward saccade, respectively. The second stimulus in the sequence was occluded with randomly positioned dots; occlusion levels were titrated by varying occluding dot width. Some neurons (11/43, 26%) showed strong responses to unoccluded stimuli and responses gradually declined with increasing levels of occlusion. These unoccluded-preferred neurons showed shape-selective responses to occluded stimuli. These neurons behaved quite like those in IT cortex during passive fixation (Kovacs et al., 1995) and their responses were consistent with a encoding of the identity of the occluded shape. Many others (21/43, 49%), however, showed weak responses to unoccluded stimuli and stronger responses under occlusion. Taken together, our results sup-

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port the idea that IT neurons encode segmented components of the image, with one sub-group encoding the occluded stimulus and other encoding the occluders.

Acknowledgement: NEI grant R01EY018839, Vision Core grant P30EY01730, P51 grant OD010425

26.4012 **A dynamic representation of shape similarity in the lateral intraparietal area**

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Visual object recognition in primates is a very efficient and reliable cognitive ability. Psychophysical studies have shown that flexibility, efficiency and performance of visual object recognition is achieved by the representation of shape similarities as opposed to the representation of shapes themselves. Stable versions of such neural representations have been found in the ventral pathway of non-human primates. However, some aspects of visual object recognition require dynamic comparisons of the shape similarity in context of a goal oriented task. This form of representation is more likely to appear in area that can integrate bottom-up sensory with top-down task relevant information. We tested whether neurons in the lateral intraparietal area (LIP) of posterior parietal cortex could fulfill this role by collating information from object specific similarity map representations to allow general decisions about whether a stimulus matches the object being looked for. We found that when animals compared two peripheral stimuli to a sample at their fovea, the response to the matching target remained stable, but the response to the distractor depended on how similar it is to the sample: the more similar, the greater the response to the distractor. Our data suggest that mental comparisons may utilize a dynamic perceptual similarity representation in LIP, which bridges object information from the ventral stream with decision making activity in pre-frontal cortex.

Acknowledgement: National Eye Institute

26.4013 **Neural responses to shape and texture stimuli in macaque area V4**

Taekjun Kim[1](taekjunkim1223@gmail.com), Wyeth Bair[1], Anitha Pasupathy[1]; [1]BIological Structure, School of Medicine, University of Washington

Functional and anatomical evidence demonstrates that visual information is processed along the dorsal and ventral visual pathways in the primate. Area V4 is an important intermediate stage of the ventral visual pathway, which is specialized for object recognition. Several studies agree that V4 neurons respond to visual shape properties (e.g., contour features along a shape boundary), and surface properties (e.g., color, brightness, and texture). However, the main role of V4 in vision has been extensively debated. In the current study, we examined which of object boundary and surface characteristics has a greater impact on V4 single unit activity by presenting simple 2D shape stimuli and texture patches to the same neurons. Our findings showed that simple 2D shape stimuli typically evoked stronger responses from V4 single units compared to texture patches contained within the receptive field or extending beyond. In many cells (>40% of our cell population), neural responses to circular texture patches were tuned to crucial dimensions of texture perception – coarseness, directionality, and regularity. However, response variation attributable to texture information was largely influenced by the cells' preference for a visual shape defined by texture stimuli. Texture stimuli that defined the surface of preferred but not non-preferred visual shape could yield response variation. Preferred visual shape of a single unit was unchanged under various texture conditions within the shapes. Unlike standard shape stimuli which affect both transient and sustained activity of V4 neurons, neural response variation due to the texture information was reflected mostly in sustained activity as a form of suppression. These results suggest that the main role of V4 neurons in object recognition is to represent shape information which is largely consistent across surface properties.

26.4014 **Exploring the role of curvature for neural shape representations across hV4 and Lateral Occipital visual field maps**

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Whilst Macaque V4's role for curvature and shape processing is well documented, the relationship between human Lateral Occipital LO-1/2 and more ventral hV4 retinotopic maps is less clear. The former regions overlap shape-selective Lateral Occipital Complex (LOC), and we previously demonstrated that LO-2 and LOC share similar (potentially curvature-based) neural shape representations. Therefore, we asked more directly whether curvature is explicitly represented in these LO maps, or if instead it is processed by hV4 in line with Macaque literature. We used radial frequency (RF) patterns to test whether degree of curvature (manipulated via amplitude), or simply the number of curves (manipulated via frequency; range 3-5), would most influence neural shape representations. This was tested in a rapid event-related fMRI experiment, using representational similarity analysis to assess patterns of activity across retinotopically- and functionally-defined regions of interest (ROIs). Neural similarity was compared to shape similarity metrics based upon amplitude, frequency, and additional predictors derived from Principal Component Analysis (PCA) on more exploratory stimulus similarity metrics. Those PCA components were 'Lobe-prominence' (degree of curve protrusion) and 'Lobe-curvature' (curvature breadth/acuteness). After controlling for low-level influences, we found three divergent influences in later visual cortex. First, frequency was only influential for LO-1, implying LO-1 is at least partially distinct from other ROIs. Amplitude was well-represented across all Lateral Occipital ROIs (LO-1/2, LO), however this is complicated by our two components. We found that 'Lobe-curvature' was somewhat influential not only for Lateral Occipital ROIs, but also for hV4. Conversely, 'Lobe-prominence' only explained variance in Lateral Occipital regions. This implies that whilst hV4 likely does process shape curvature to some extent, its representation is nevertheless distinct from that of our Lateral Occipital ROIs. On the basis of these results, we suggest the Lateral Occipital shape representation may in part be based upon shape protrusions.

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26.4015 **Radial frequency tuning in human visual cortex**

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Radial frequency (RF) patterns are shape stimuli defined by a sinusoidal modulation of a circle's radius. Low frequency RF patterns, with few modulations around the perimeter, are processed by global, mid-level shape mechanisms, however the neural locus of these mechanisms in humans is not well understood. We used fMRI to measure neural responses to a large range of RFs, and modeled neural tuning to RF in early, lateral and ventral visual cortex. Responses were modeled by a Gaussian neural model defined in RF space, where each voxel's tuning to RF was defined by the model which generated a response that best predicted the fMRI data. To quantify this pattern, we measured tuning profiles to RF for visual areas V1, V2, V3, V4, VO1, VO2, LO1, LO2 and object-selective LOC. Low, globally processed RF tuning was localised to lateral occipital cortex (LO) in all subjects. Specifically, tuning to global RFs first emerged in visual field maps LO1 and LO2, and persisted through LOC. In addition, we correlated RF tuning profiles from each area against stimulus contrast energy and shape defined by circularity. Only LO2 and LOC profiles were significantly better explained by sensitivity to shape over contrast energy. All early and ventral areas showed tuning to high, locally processed RFs and were more strongly correlated with stimulus contrast energy over shape. We replicated our results using a control stimulus set where all RFs were combined with the same high-frequency contour modulations to match stimuli for low-level differences, showing LO responses were driven by the global shape of low RFs which remained constant across both stimulus sets. Our results suggest a shape processing pathway through lateral occipital cortex, where global shape representations are formed in LO2, likely providing input to LOC where more complex representations of objects are formed.

Acknowledgement: BBSRC grants BB/L007770/1 and BB/P007252/1

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26.4016 **Decoding face pareidolia in the human brain with fMRI**

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A common human experience is face pareidolia, whereby illusory faces are perceived in inanimate objects. A unique aspect of pareidolia is that the objects are typically perceived simultaneously as both an illusory face and an inanimate object. Ventral visual areas such as the lateral occipital complex (LOC) and fusiform face area (FFA) in human occipital-temporal cortex are category-selective and respond to either objects or faces respectively. Consequently, it is unclear how these category-selective regions process stimuli with a dual face/object identity. Here we use fMRI to probe how visual stimuli with a persistent dual identity are processed by face and object-selective areas. We used a diverse image set containing natural examples of pareidolia in a wide variety of everyday objects. Critically, we created a yoked image set that was matched for object content and visual features but did not contain any illusory faces. We used a yoked block design to measure patterns of BOLD activation in response to objects where pareidolia was present or absent. Standard functional localizers were used to define category-selective areas. Using standard leave-one-run out classification, a linear support vector machine (SVM) could decode pareidolia objects versus non-face objects from both early visual cortex (V1), and higher-level category-selective areas (LOC and FFA). Importantly, in both LOC and FFA the classifier could successfully decode the presence or absence of pareidolia faces in new image sets that were not used for training the classifier, demonstrating generalization. In contrast, the presence of pareidolia could not be decoded in V1 when different image sets were used for training versus testing the classifier. This suggests that both FFA and LOC respond to the presence of illusory faces in inanimate objects. Interestingly, cross-classification of object identity was not successful in either FFA or LOC, suggesting face pareidolia is strongly represented in these areas.

26.4017 **A tool for automatic identification of cerebral sinuses and corresponding artifacts in fMRI**

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Functional magnetic resonance imaging (fMRI) is a widely used method for investigating the cortical mechanisms of visual perception. Given that fMRI measures oxygenation-related changes in hemodynamics, it is critical to understand the factors governing the accuracy with which hemodynamics reflect neural activity. We conducted ultra-high-resolution fMRI in human visual cortex during a simple event-related visual localizer experiment (7T, 0.8-mm isotropic, 2.2-s TR, 84 slices, gradient-echo EPI), and also collected whole-brain anatomical T1- and T2-weighted volumes (3T, 0.8-mm isotropic). We find that major cerebral sinuses (superior sagittal sinus, straight sinus, and left and right transverse sinuses) can be clearly identified by computing the ratio of the T1- and T2-weighted volumes (Salimi-Khorshidi et al. 2014), and we show that these sinuses are nearly perfectly aligned across subjects after transformation to volumetric MNI space. We then construct a sinus atlas and develop a software tool that automatically predicts the location of the sinuses given only a T1-weighted anatomical volume obtained for a subject. We show that this tool accurately reproduces manual segmentations of the sinuses in our subjects. Importantly, we demonstrate that regions of the cortical surface located near the sinuses correspond to regions with signal dropout and unreliable fMRI responses in our functional data. These sinus-affected regions are not only located near hV4 as previously reported (Winawer et al. 2010), but are also located near many other regions in occipital, parietal, and temporal cortex. Because the atlas is accurate, automated, and easy to use, we suggest that it be routinely used to identify cortical regions that are likely to suffer from imaging artifacts, thereby avoiding the need to exclude regions based on ad hoc, subjective measures and aiding proper interpretation of fMRI data.

Scene Perception: Models and other

Saturday, May 20, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4018 **Places: An Image Database for Deep Scene Understanding**

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The rise of multi-million-item dataset initiatives has enabled machine learning algorithms to reach near-human performances at object and scene recognition. Here we describe the Places Database, a repository of 10 million pictures, labeled with semantic categories and attributes, comprising a quasi-exhaustive list of the types of environments encountered in the world. Using state of the art Convolutional Neural Networks (CNN), we show performances at natural image classification from images collected in the wild from a smart phone as well as the regions used by the model to identify the type of scene. Looking into the representation learned by the units of the neural networks, we find that meaningful units representing shapes, objects, and regions emerge as the diagnostic information to represent visual scenes. With its high-coverage and high-diversity of exemplars, Places offers an ecosystem of visual context to guide progress on currently intractable visual recognition problems. Such problems could include determining the actions happening in a given environment, spotting inconsistent objects or human behaviors for a particular place, and predicting future events or the cause of events given a scene.

26.4019 **Similarities Between Deep Neural Networks and Brain Regions In Processing Good and Bad Exemplars of Natural Scenes**

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The layers of Deep Neural Networks (DNNs) have shown some commonality with processing in the visual cortical hierarchy. It is unclear, however, whether DNNs capture other behavioral regularities of natural scenes, e.g. the representativeness of an image to its category. Humans are better at categorizing and detecting good (more representative of category) than bad exemplars of natural scenes. Similarly, prior work has shown that good exemplars are decoded better than bad exemplars in V1 as well as higher visual areas such as the retrosplenial cortex (RSC) and the parahippocampal place area (PPA). Here we ask whether a DNN, that was not explicitly informed about representativeness of its training set, shows a similar good exemplar advantage, and if so in which layers do we see this effect. We used good and bad exemplars from six categories of natural scenes (beaches, city streets, forests, highways, mountains and offices) and processed them through the pre-trained Places205-AlexNet. We asked both whether this DNN could distinguish good from bad scenes, as well as whether 6-way category classification differed for good and bad exemplars. Classification was performed using the feature space of each layer separately. Our results show that while in the lowest layer (conv1) there is insufficient information to make a good vs. bad discrimination, the layer (fc7) (the second highest fully connected layer) can clearly make this discrimination. Furthermore, the six-way categorization was better for good exemplars than bad exemplars in lower and higher layers, although categorization accuracy increases overall at the higher layers. This parallels results seen in V1, RSC and PPA, and suggests that the DNN learns statistical regularities that distinguish good from bad exemplars without such information being explicitly encoded into the training set.

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26.4020 **Computational mechanisms for identifying the navigational affordances of scenes in a deep convolutional neural network**

Michael Bonner[1](michafra@mail.med.upenn.edu), Russell Epstein[1]; [1]University of Pennsylvania

A central component of spatial navigation is determining where one can and cannot go in the immediate environment. For example, in indoor environments, walls limit one's potential routes, while passageways facilitate movement. In a recent set of fMRI experiments, we found evidence sug-

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gesting that the human visual system solves this problem by automatically identifying the navigational affordances of the local scene. Specifically, we found that the occipital place area (OPA), a scene-selective region near the transverse occipital sulcus, appears to automatically encode the navigational layout of visual scenes, even when subjects are not engaged in a navigational task. Given the apparent automaticity of this process, we predicted that affordance identification could be rapidly achieved through a series of purely feedforward computations performed on retinal inputs. To test this prediction and to explore other computational properties of affordance identification, we examined the representational content in a deep convolutional neural network (CNN) that was trained on the Places database for scene categorization but has also been shown to contain information relating to the coarse spatial layout of scenes. Using representational similarity analysis (RSA), we found that the CNN contained information relating to both the neural responses of the OPA and the navigational affordances of scenes, most prominently in the mid-level layers of the CNN. We then performed a series of analyses to isolate the visual inputs that are critical for identifying navigational affordances in the CNN. These analyses revealed a strong reliance on visual features at high-spatial frequencies and cardinal orientations, both of which have previously been identified as low-level stimulus preferences of scene-selective visual cortex. Together, these findings demonstrate the feasibility of computing navigational affordances in a feedforward sweep through a hierarchical system, and they highlight the specific visual inputs on which these computations rely.

26.4021 Expecting and detecting objects in real-world scenes: when do target, nontarget and coarse scene features contribute?

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Humans excel at finding objects in complex natural scenes but understanding this behaviour has been difficult because natural scenes contain targets, nontargets and coarse scene features. Here we performed two studies to elucidate object detection on natural scenes. In Study 1, participants detected cars or people in a large set of natural scenes. For each scene, we extracted target-associated features, annotated nontarget objects, and extracted coarse scene structure and used them to model detection performance. Our main finding is that target detection in both person and car tasks was predicted using target and coarse scene features, with no discernible contribution of nontarget objects. By contrast, nontarget objects predicted target rejection times in both person and car tasks, with contributions from target features for person rejection. In Study 2, we sought to understand the computational advantage of context. Context is commonly thought of reducing computation by constraining locations to search. But can it have a more fundamental role in making detection more accurate? To do so, scene context must be learned independently from target features. Humans, unlike computers, can learn contextual expectations separately when we see scenes without targets. To measure these expectations, we asked subjects to indicate the scale, location and likelihood at which targets may occur in scenes without targets. Humans showed highly systematic expectations that we could accurately predict using scene features. Importantly, we found that augmenting state-of-the art deep neural networks with these human-derived expectations improved performance. This improvement came from accepting poor matches at highly likely locations and rejecting strong matches at unlikely locations. Taken together our results show that humans show systematic behaviour in detecting objects and forming expectations on natural scenes that can be predicted and understood using computational modelling.

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26.4022 Symmetry in the Eye of the Beholder

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We study how subjective perception of symmetry can be computationally explained by features at different levels. We select 149 images with varying degrees of symmetry from photographs and movie frames and collect responses from 200 subjects. Each subject is shown 50 random images and asked to rate each image with one of four options: Not symmetric, Somewhat symmetric, Symmetric, and Highly symmetric. We measure the bilateral symmetry of an image by comparing CNN features across multiple levels between two vertical halves of an image. We use the AlexNet model pre-trained on the ImageNet dataset for extracting feature maps at all 5 convolutional layers. The extracted feature maps of the two bilateral halves are then compared to one another at different layers and spatial levels. The degree of similarity on different feature maps can then be used to model the range of symmetry an image can be seen to have. We train a multiclass SVM classifier to predict one of the four symmetry judgements based on these multi-level CNN symmetry scores. Our symmetry classifier has a very low accuracy when it needs to predict all observers' responses equally well on individual images. However, our classification accuracies increase dramatically when each observer is modeled separately. Our results suggest that symmetry is in fact in the eye of the beholder: While some observers focus on high-level object semantics, others prefer low or mid-level features in their symmetry assessment.

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26.4023 The Relationship Between Salience and Meaning During Real-World Scene Viewing

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While there is evidence that both visual salience and previously stored scene knowledge influence scene viewing behavior, the relationship between them and viewing behavior is unclear. The present study investigated the relationship between stimulus-based saliency and knowledge-based scene meaning. Sixty-five participants performed a scene memorization task while their eye movements were recorded. Each participant viewed 40 real-world scenes for 12 seconds each. A duration-weighted fixation density map for each scene was computed across all 65 participants to summarize viewing behavior. A saliency map for each scene was computed using the Graph-Based Visual Saliency model (Harel, Koch, & Perona 2006). Finally, a meaning map was generated for each scene using a new method in which people rated how informative/recognizable each scene region was on a 6-point Likert scale. Specifically, each scene was sampled using overlapping circular patches at two spatial scales (300 3° patches or 108 7° patches). Each unique patch was then rated by participants on Amazon Mechanical Turk (N=165) that rated a random set of ~300 patches. The 3° and 7° rating maps were smoothed using interpolation, and then averaged together to produce a meaning map for each scene. The unique and shared variance between the fixation density map and the saliency and meaning maps for each scene were computed using multiple linear regression with salience and meaning as predictors. The squared partial correlation showed that on average meaning explained 50% (SD=11.9) of the variance in scene fixation density while salience explained 35% (SD=12.5). The squared semi-partial correlation indicated that on average meaning uniquely explained 19% (SD=10.6) of variance in fixation density while salience only uniquely accounted for 4% (SD=4.0). These results suggest that scene meaning is a better predictor of viewing behavior than salience, and stored scene-knowledge uniquely accounts for relevant scene regions not captured by salience alone.

Acknowledgement: National Science Foundation (BCS-1151358)

26.4024 THREAT - A database of line-drawn scenes to study threat perception

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Efficient extraction of threat information from scene images is a remarkable feat of our visual system, but little is known about how it is accomplished. To facilitate studies of threat perception with well-controlled scene images, we created a set comprising 500 hand-traced line drawings of photographic visual scenes depicting various dimensions of threat. We used color-photo scene images previously reported in Kveraga et al. (2015) depicting direct

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threat, indirect threat, threat aftermath, and low threat scenes. Sixty participants were randomly assigned to rate all 500 scenes answering one of three questions: 1) How much harm might you be about to suffer in this scene if this was your view of the scene?; 2) How much harm might someone (not you) be about to suffer in this scene?; 3) How much harm might someone (not you) have already suffered in this scene?. Another 134 participants were randomly assigned to rate the images on various other threat dimensions. The mean ratings on these threat dimensions were submitted to a factor analysis, which resulted in three distinct factors including Affect (comprised of perceived emotional intensity, physical and psychological harm, and affect), Proximity (comprised of perceived threat clarity, its proximity in space and time, and degree of motion), and Agency (comprised of perceived human and animal agency, and whether inanimate objects present in the scene could be used as a potential weapon). Mean ratings on three harm questions and three factors were then submitted to cluster analyses, which grouped images into six distinct categories. This unique set of images, accompanied by ratings assessing multiple dimensions of threat and their clusters, is well suited for investigating research questions on emotion regulation and threat perception in neurotypical and clinical populations. Information on using it can be found at http://www.kveragalab.org/stimuli.html.

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26.4025 **The Use of Infographics to Evaluate Visual Context Processing** Beliz Hazan[1](beliz.hazan@gmail.com), Daniel D. Kurylo[1,2]; [1]The Graduate Center, CUNY, [2]CUNY Brooklyn College

The use of contextual information may be explored with infographics (informational graphics). Infographics is described as a combination of text, visual pictures, and graphs to demonstrate data, information and knowledge, as well as convey information through visual storytelling. Comprehending infographics has been associated with several cognitive functions, including attention, visuospatial perception, and visual working memory, as well as perception of holistic characteristics, a process termed Gestalt Thinking. The study described here aimed to develop an assessment tool of context processing by using infographics at different perceptual and cognitive levels. Observers viewed complex images and were asked specific questions about information contained within the image. Level 1 test items contained relationships among basic stimulus features, such as color and luminance, which required perceptual comparison and reasoning. Level 2 test items contained conceptual relationships among stimulus components, which required deductive reasoning. Performance was indexed as the level of feature disparity, where critical visual information was progressively made more salient. Assessments of verbal comprehension (vocabulary and similarity) and perceptual reasoning (block design and matrix reasoning) was based upon a standardized test (WASI II). Results indicated that unlike Level 1 infographics, a significant positive correlation existed between Level 2 infographics and matrix reasoning, which involves fluid intelligence, knowledge of part-whole relationships, and perceptual organization (Spearman rs=.897, p< .05). Unexpectedly, a significant negative correlation existed between Level 2 infographics and the similarities subtest, which involves crystalized intelligence and verbal concept formation (rs =-.901, p< .001). Results indicate that comprehension of Level 2 infographics, which rely on global relationships, is enhanced by visuospatial and perceptual organization ability, but weakened by greater ability in focusing on specific concepts. Results support a model of contextual processing that emphasizes global relationships and deemphasizes attention focus on image components.

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26.4026 **Anchoring spatial predictions: Evidence for the critical role of anchor objects for visual search in scenes.** Sage Boettcher[1,2](sage.boettcher@psy.ox.ac.uk), Eric Dienhart[1], Melissa Vo[1]; [1]Scene Grammar Lab, Goethe University Frankfurt, [2]Brain & Cogntion Lab, Oxford University

Real-world scenes follow certain rules known as scene grammar, which allow for extremely efficient visual search. In the current work, we seek to understand what role objects, specifically anchor objects, hold during a visual search in 3D rendered scenes. Anchors are normally, large and diagnostic of the scene they are found in. However, what distinguishes anchors from other objects is the specific spatial information which they carry regarding other objects. Our lab previously showed that participants have a precise notion of where objects belong relative to anchors but not relative to other objects (Boettcher & Vo, 2016). In a series of two eye-tracking experiments we tested what role anchor objects occupy during visual search. In Experiment 1, participants searched through scenes for an object which was cued in the beginning of each trial. Critically, in half of the scenes a target relevant anchor was swapped for an irrelevant, albeit semantically consistent, anchor. This lead to marginally faster reaction times and time to first fixation on the target. Additionally, subjects covered significantly less of the scene when the anchor was present compared to swapped. These marginal effects might underestimate the role of anchors owed to the sheer speed of the search, partly due to the guidance available from the physical features of the target. Therefore, in Experiment 2 participants were briefly shown a target-absent scene before the target cue. Search was then restricted to a gaze-contingent window. Participants were now significantly faster to respond, and the area of the scene which they covered was significantly smaller for trials with congruent compared to swapped anchors. Moreover, observers were marginally faster at fixating the target in the anchor present trials. Taken together, anchor objects seem to play a critical role in scene grammar, and specifically in executing it during visual search within scenes.

Acknowledgement: DFG grant VO 1683/2-1 to MLV.

26.4027 **Aging alters neural processing underlying figure-ground organization** Allison Sekuler[1](allisonsekuler@mac.com), Jordan Lass[1], Ali Hashemi[1], Patrick Bennett[1], Mary Peterson[2]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University, [2]Department of Psychology and Cognitive Science Program, University of Arizona

Aging decreases observers' ability to segment figure from ground, but what neural mechanisms underlie age-related changes in figure-ground organization? We measured EEG in older and younger observers while they viewed stimuli comprising eight alternating convex and concave regions, and indicated whether a red probe was "on" or "off" the region they perceived as figure. There were two types stimuli: (1) high-competition stimuli, in which all convex regions were one colour and all concave regions were a different colour; these stimuli support two competing interpretations: convex or concave figures in front of a ground of uniformly coloured regions of the other type; (2) low-competition stimuli, in which all concave regions were the same colour, but convex regions were each coloured differently, favouring the interpretation of convex figures of varying colours in front of a uniformly coloured background comprising concave regions. In younger observers, the amplitude of the parieto-occipital N250 event-related potential (ERP) was more negative for high- than low-competition stimuli. This difference was absent in older observers. Furthermore, the N250 amplitude difference was inversely correlated with behaviour: Individuals showing a larger N250 difference between high- and low-competition stimuli reported seeing the convex regions as figures equally often in high- and low-competition stimuli, whereas individuals with similar N250 amplitudes across conditions were less likely to perceive convex regions as figure in high- than low-competition stimuli. The brain-behaviour correlation also separated observers by age: Older observers generally showed a large behavioural difference between high- and low-competition conditions, but smaller ERP differences; whereas younger observers generally showed a small behavioural difference, but larger ERP differences. These results suggest that figure-ground organization is driven by mechanisms sensitive to the degree of competition between stimulus interpretations, and that the age-related reduction in resolving high figure-ground competition in healthy aging is related to an altered neural response.

Acknowledgement: CFI, CIHR, CRC, NSF, NSERC, NSF, ONR

Scene Perception: Neural mechanisms

Saturday, May 20, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4029 **Time-resolved fMRI decoding reveals spatio-temporal characteristics of scene processing network** Zhengang Lu[1](zhengang.lu@jhu.edu), Soojin Park[1]; [1]Department of Cognitive Science, Johns Hopkins University

Current functional brain imaging studies have identified a number of areas involved in scene processing in the human brain, including the Parahippocampal Place Area (PPA), the Occipital Place Area (OPA), and the Retrosplenial Complex (RSC). This spatial loci of scene processing have to be combined with the temporal characteristics of brain activity to provide a comprehensive understanding of what and how each brain area represents scene information. Using a recently developed time-resolved repetition paradigm, we combined fMRI and multi-voxel pattern decoding method to show a spatial and temporal characterization of brain responses to scene images varied in spatial boundary (open vs. closed) and scene content (natural vs. urban). Critically, the repetition lags between the first and second scene image were manipulated in small step (33 ms) starting from 66 ms to 1033 ms to reconstruct time courses of spatial boundary and scene content representation in each functionally localized scene-related brain area. We observed that the PPA showed a similar time course of both spatial boundary and scene content information, suggesting that the temporal characteristics of the PPA might be robust to various scene properties. Interestingly, the OPA showed an opposite time course for representing spatial boundary and scene content information, suggesting that the OPA might process spatial boundary and scene content in a competing manner in time. In contrast, RSC didn't show any relation in representing spatial boundary and scene content in time. These findings suggest that different scene areas not only differ in what types of scene information it represents but also in temporal profiles of how to extract information from scenes. Our preliminary results provide a spatio-temporal-resolved fMRI approach as a tool to further understanding the neural dynamics in the scene processing network during the first second of scene perception.

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26.4030 Evidence for a grid-like representation of visual space in humans Joshua Julian[1](jjulian@sas.upenn.edu), Alex Keinath[1], Giulia Frazzetta[1], Russell Epstein[1]; [1]Department of Psychology, University of Pennsylvania

Most cortical regions represent visual space retinotopically. However, many behaviors would benefit from a non-retinotopic representation of visual space. Grid cells in the entorhinal cortex (EC) may provide a neural substrate for such a non-retinotopic representation. In freely navigating rodents, grid cells fire when the animal's body occupies a hexagonal lattice of spatial locations along the chamber floor. In head-fixed monkeys, on the other hand, grid cells fire when the animal directs its gaze to a hexagonal lattice of locations on the visible screen (Killian et al., 2012). To determine whether similar scene-based grid responses can be identified in humans, we scanned participants with fMRI while tracking their gaze during an unconstrained visual search task in which they had to find a target letter ('L') among numerous distractors letters ('T's). Building on fMRI methods previously used to identify the grid signal during virtual navigation (Doeller et al., 2010), we used a quadrature filter approach to measure fMRI responses as a function of gaze movement direction. In particular, we first extracted gaze movement directions modulo 60°, thus equating all 6-Fold symmetric gaze movement directions. Then, using half of the fMRI data, we computed the rotation of the gaze movement directions that maximally modulated EC activity. Using this fit rotation angle, we predicted EC activity in the withheld fMRI data. Examination of this independent data confirmed that there was significant modulation of EC activity bilaterally as a function of gaze movement direction. Follow-up analyses confirmed that this modulation only exhibited the 6-fold rotational symmetry characteristic of grid cell firing, and not 4- or 8-fold symmetries. These results mark the first evidence of a grid-like representation of visual space in humans, and suggest that the same mechanisms supporting the cognitive map of navigational space may also support a map of visual space.

26.4031 Discriminating multimodal from amodal representations of scene categories using fMRI decoding Yaelan Jung[1](jung.yaelan@gmail.com), Bart Larsen[2], Dirk Bernhardt-Walther[1]; [1]Department of Psychology, University of Toronto, [2]Department of Psychology, University of Pittsburgh

Previous studies have shown that, unlike V1 and A1, temporal, parietal, and prefrontal cortices process sensory information from multiple sensory modalities (Downar et al, 2000). However, it is unknown whether neurons in these areas process sensory information regardless of modality (amodal), or whether these areas contain separate but spatially mixed populations of neurons dedicated to each sensory modality (multimodal). Here we used fMRI to study how temporal, parietal, and prefrontal areas represent scene categories in the case of conflicting evidence from visual and auditory input. For instance, participants were shown an image of a beach and played office sounds at the same time. If a brain area processes visual and auditory information separately, then we expect scene categories to be decodable from at least one modality, as conflicting information from the other modality is not processed by the same neurons. However, in an area where neurons integrate information across sensory modalities, conflicting information from visual and auditory inputs should lead to interference and hence a deterioration of the neural representation of scene categories. In our experiment, we were able to decode scene categories from fMRI activity in temporal and parietal areas for visual or auditory stimuli. By contrast, in prefrontal areas, we could decode neither visual nor auditory scene categories in this conflicting condition. Note that both types of scene categories were decodable from the image-only and sound-only conditions, when there was no conflicting information from the other modality. These results show that even though temporal, parietal, and prefrontal cortices all represent scene categories based on multimodal inputs, only prefrontal cortex contains an amodal representation of scene categories, presumably at a conceptual level.

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26.4032 Retinotopic organization of scene area in macaque inferior temporal cortex and its implications for development Michael Arcaro[1](Michael_Arcaro@hms.harvard.edu), Margaret Livingstone[1]; [1]Department of Neurobiology, Harvard Medical School

Primates have specialized domains in inferior temporal (IT) cortex that are responsive to particular object categories. Recent fMRI studies have shown that retinotopic maps cover much of category-selective IT cortex in humans and monkeys. So far, retinotopy in monkey IT cortex has been reported within and around the lower bank of the STS (Kolster et al. 2014; Janssens et al. 2014). In the present study, we confirm this previously reported retinotopy and extend these prior findings by examining retinotopy in the ventral-most regions of IT - occipital temporal sulcus (OTS). We identified two retinotopic areas, referred to as OTS1 and OTS2, which have not been described previously in the macaque. These new regions are located ventral to retinotopic areas V4A and PIT. Both regions contain contralateral representations of the periphery with little coverage of central visual space. OTS1/2 show selectivity for scenes compared to objects, faces, and bodies. Our results resolve the relationship between scene-selective areas in humans (Aguirre et al. 1996, Epstein and Kanwisher 1998) and primates (Nasr et al. 2011; Kornblith et al. 2013). OTS1/2 overlap with the functionally defined place area, LPP. Further, the visual field organization of OTS1/2 corresponds well with the organization of scene-selective retinotopic areas PHC1/2 in humans (Arcaro et al. 2009). Our data provide new evidence that monkey LPP is the homologue to human area PPA. Our results illustrate parallels in the retinotopic organization between primate species. First, the broad eccentricity bias across human ventral temporal cortex (Hasson et al. 2002) is clearly present in macaque IT cortex. Second, we find that the extent of retinotopy in macaque IT cortex roughly matches that in humans. Recent results from our lab suggest that this retinotopic organization is present at birth and is likely fundamental in guiding experience-dependent development of IT.

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26.4033 Eye movements during scene viewing are causally dependent on the occipital place area Jennifer Henry[1](jrhenry1127@gmail.com), George Malcolm[2], Edward Silson[1], Chris Baker[1]; [1]Laboratory of Brain and Cognition, NIMH, NIH, [2]School of Psychology, University of East Anglia, UK

Despite the huge variability of visual properties in our environment, we can efficiently process the scenes we are embedded in. This processing is supported by three cortical regions: parahippocampal place area (PPA), medial place area (MPA) [or retrosplenial complex, RSC], and occipital place area (OPA). Within the contexts of recognition and navigation, the functions of these regions are generally studied in terms of the visual information they respond to. Here we move beyond these tasks to investigate the role of OPA in guiding eye movements during scene viewing. OPA is i) located in occipito-parietal cortex, likely feeding information into parts

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of the dorsal pathway critical for eye movements, and ii) contains retinotopic representations of the contralateral visual field. OPA was disrupted with transcranial magnetic stimulation (TMS) while participants searched scenes for 1s. Participants then chose which of two objects had been in the previous scene. On half of the trials, participants received repetitive TMS: a five pulse train over 500ms, starting at scene onset. Half of the participants received TMS to rOPA and half to rOFA (occipital face area), which also exhibits a contralateral visual field bias though is more responsive to face stimuli. If OPA plays a causal role for gaze guidance in scenes, then TMS to rOPA, but not rOFA, should disrupt the eye movement pattern. Given OPA's contralateral representation, eye movements should be biased toward the ipsilateral visual field following rOPA, but not rOFA stimulation. There was an overall left-to-right gaze pattern across all conditions, despite every trial starting at center. Critically, the average fixation position for participants in the rOPA condition was biased toward the ipsilateral visual field and saccade latencies to the ipsifield were shorter. These results suggest that OPA might play a causal role in analysing local scene information for eye movement guidance.

26.4034 Category discrimination of early electrophysiological responses reveals the time course of natural scene perception

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Humans have the remarkable ability to categorize complex scenes within a single glance. Which properties of scenes make this feat possible, and what is the time course of this process? Neural representations of scene categories for line drawings and colour photographs have been shown to elicit similar responses in scene-selective cortex. Together with previous investigations highlighting the importance of surface features for scene identification, these results suggest that both structure and surface features play an integral role in perceiving and understanding our environment. Within the spatial domain, these features may be closely interwoven in the human brain. Within the temporal domain, however, they may elicit distinct patterns along a hierarchy of visual processing. To investigate these questions, the present study used electroencephalography (EEG) to examine the time course of scene processing (beach; city; forest; highway; mountain; office) for colour photographs and line drawings (stimulus-type) in the human visual system. Participants (N=16) performed a blocked scene-memorization task during observation of colour photographs and line drawings. An initial event-related potential (ERP) analysis revealed dissociable response patterns across scene categories over the occipital pole for early visually-evoked components P1 and P2. Furthermore, line drawings evoked an overall higher P1 amplitude, while colour photographs evoked a higher P2 peak. Additional differences across stimulus-type were distributed throughout cortex. To investigate these response patterns in greater detail, we performed an analysis examining the grand-averaged correlations for within-category versus across-category discriminations during the time course of scene processing. This analysis revealed that significant discriminations of scene categories in line drawings emerge earlier (~80ms) than colour photographs (~100ms). Critically, these findings provide evidence that basic-level categorization of scenes can occur earlier in visual processing than object-class detection (e.g., animal detection), and further suggest that differences in visual feature processing emerge across the temporal domain for natural scene perception.

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26.4035 Artificially-generated scenes demonstrate the importance of global scene properties for scene perception

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A recent surge of behavioral, neuroimaging, and electrophysiological studies highlights the significance of global scene properties, such as spatial boundary and naturalness, for scene perception and categorization. The stimuli used in these studies are oftentimes real-world naturalistic scene images, which while essential for maintaining ecological validity, also pose a real challenge for interpretation. Specifically, since real-world scenes vary dramatically in physical stimulus properties (e.g. color) and range of semantic categories they span, it is difficult to isolate the unique role that global scene properties play in scene processing. To overcome this challenge, the present study used a set of computer-generated scene stimuli (Lowe at al., 2016) that were designed to control for two global scene properties (spatial boundary and naturalness) while minimizing and controlling for other sources of scene information, such as color and semantic category. The set comprised of 576 individual grayscale scene exemplars spanning 12 spatial layouts and 12 textures for each combination of naturalness (man-made/natural) and spatial boundary (open/closed). We presented these artificial scenes to participants while their Event-Related Potentials (ERPs) were recorded. We aimed to establish whether the artificial scenes would generate similar electrophysiological signatures of naturalness and spatial boundary previously obtained using real-world scene images (Harel et al., 2016). Strikingly, we found that similar to previous work, the peak amplitude of the P2 ERP component was sensitive to both the spatial boundary and naturalness of the scenes despite vast differences between the stimuli. In addition, we also found earlier effects of spatial boundary and naturalness, expressed as a modulation of the amplitude of the P1 and N1 components. These results suggest that naturalness and spatial boundary have a robust influence on the nature of scene processing. This influence is independent of scene category and color, and might be observed earlier than previously thought.

26.4036 Neurodynamics and hemispheric lateralization in threat and ambiguous negative scene recognition

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Efficient threat detection and appropriate action are critical for survival. However, some stimuli are merely negative without an impending threat and may offer useful clues about past or future dangers. We have shown previously (Kveraga et al., 2015) that threat and merely negative scene images are well discriminated and activate distinct brain networks in fMRI. However, the neurodynamics and hemispheric contributions underlying this process have not been studied. Methods: In this MEG study, we employed bilaterally presented threat or merely negative scene images paired with contextually matched neutral scenes in a 2AFC paradigm. Participants (N=64) had to identify the threatening or negative scene in each pair via a key press corresponding to the side of presentation. We extracted source-localized MEG activity from five ROIs in both hemispheres: fusiform face area (FFA), posterior STS (pSTS), periamygdaloid cortex (PAC), parrahippocampal cortex (PHC), and orbitofrontal cortex (OFC). Results: When threat or merely negative scenes were presented in the left visual hemifield, the contralateral right hemisphere (RH) and the ipsilateral left hemisphere (LH) showed significantly greater activation starting at about 300-400 ms for threat vs. merely negative scenes. This threat amplitude advantage was significantly greater in LH. Conversely, when threat or merely negative scenes were presented in the right visual hemifield, the contralateral LH generally had a phase lead in activity for threat vs. merely negative stimuli but no amplitude difference, while the ipsilateral RH had higher activity to merely negative scenes late in the trial, beginning at ~700 ms. Conclusions: Our findings show that deciding between two scene images leads to differential hemispheric dynamics. Threat images evoke greater activity when presented on the left, in both LH and RH, while merely negative images evoke increased later activity when presented in the right hemifield.

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26.4037 Dissociating scene navigation from scene categorization: Evidence from Williams syndrome

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Recent functional magnetic resonance imaging (fMRI) evidence suggests that human visual scene processing is supported by at least two functionally distinct systems: one for visually-guided navigation, including the

occipital place area (OPA), and a second for scene categorization (e.g., recognizing a kitchen vs. a beach), including the parahippocampal place area (PPA). However, fMRI data are correlational, and a stronger test of this "two systems for visual scene processing" hypothesis would ask whether it is possible to find cases of neurological insult impairing one ability independent of the other. Toward this end, here we tested visually-guided navigation and categorization abilities in adults with Williams syndrome (WS), a genetic developmental disorder involving cortical thinning in and around the posterior parietal lobe (potentially including OPA, but not PPA). WS adults and mental-age matched (MA) controls (i.e., 7 year old typically-developing children) completed a visually-guided navigation and a categorization task. In the visually-guided navigation task, participants viewed images of scenes, and indicated which of three doors (left, center, or right) they would be able to exit along a complete path on the floor. In the categorization task, participants viewed the exact same scene images, and indicated whether each depicted a bedroom, kitchen, or living room. If visual scene processing is supported by independent visually-guided navigation and categorization systems, then WS adults will be impaired on the visually-guided navigation task, but not on the categorization task. Indeed, we found that WS adults performed significantly worse on the visually-guided navigation task compared to the categorization task, relative to MA controls. These findings provide the first causal evidence for dissociable visually-guided navigation and categorization systems, and further suggest that this distinction may have a genetic basis. Future studies will ask whether patients with PPA damage show the opposite profile from WS, for a full double dissociation.

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3D Perception: Shape

Saturday, May 20, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4038 Inferring the deformation of unfamiliar objects

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When objects are deformed by external forces (e.g. a crushed can or twisted rag), the resulting shape is a complex combination of features from the original shape and those imparted by the transformation. If we observe only the resulting shape, distinguishing the origin of its various features is formally ambiguous. However, in many cases the transformation leaves distinctive signatures that could be used to infer how the object has been transformed. Here we investigated how well observers can identify the type and magnitude of deformations applied to unfamiliar 3D shapes. We rendered objects subjected to physical simulations of 12 shape-transforming processes (e.g., twisting, crushing, stretching). Observers rated the magnitude of object deformation at different stages of the transformation process (e.g., barely twisted vs. strongly twisted). Another group viewed one transformed object at a time and ranked other objects-which were submitted to the same or one of the 11 other transformations-according to their similarity to the test object in terms of the applied transformation. A third group viewed a subset of the objects and painted on the surface to indicate which regions appeared most informative about the type of transformation. We find that observers can estimate the magnitude of deformation of unfamiliar objects without knowing their pre-transformed shapes. They can infer specific causal origins from these deformations, reflected in their ability to identify other objects subjected to the same transformation. We also identify the shape features underlying these inferences by comparing the painting responses to the physical mesh deformations. Our findings show that observers can infer transformations from object shape. This ability to infer the causal origin of objects is potentially useful in estimating their physical properties (e.g., stiffness), predicting their future states, or judging similarity between different objects.

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26.4039 Depth-Inversion "Easillusions" and "Hardillusions": Differences for Scenes and Faces

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Introduction: Two depth-inversion (DI) illusions, where viewers perceive depth structure opposite to the stimulus's physical depth, are hollow masks and reverspectives [Wade & Hughes, 1999]. For faces, one explanation is that face-specific 3D stored knowledge and a general convexity bias overcome data-driven depth cues to produce DI. For reverspectives, stored general perspective rules (e.g., that retinal trapezoids are rectangles slanted in physical space with their long retinal edge closer to viewer) may account for the DI [Gregory, Phil. Trans. R. Soc. B, 2005]. We call such easily obtained DI illusions "Easillusions". Rationale for present study: We investigated whether humans can downplay stored knowledge and rules to obtain DI "hardillusions" for stimuli in which stored knowledge and rules oppose, rather than favor, DI [Papathomas et al. ECVP 2015]. Examples of such stimuli are normal, convex 3-D faces and "proper-perspectives", in which the retinal trapezoids are consistent with the depth of the physical surfaces. However, our 2015 study included only unpainted masks and fragments of reverse-perspectives. Methods: This study included a complete reverspective and realistically painted convex masks. Stimuli were both easillusions (hollow mask, reverspective) and hardillusions (convex mask, proper-perspective). Also, all stimuli were either realistically painted or unpainted. We assessed how long it took 16 subjects to obtain DI. Results: Painted reverspectives tended to produce DI faster than unpainted ones, whereas painted proper perspectives were much slower than unpainted ones. For faces, the difference for obtaining DI between painted and unpainted faces was much smaller both for the hollow and convex masks. The only stimuli that no subject was able to get DI were painted convex masks. Conclusions: Perspective painted cues played a much stronger role than facial painted cues, providing additional evidence that facial 3D geometry plays a larger role than scene 3D geometry.

26.4040 Distortions in perceived depth magnitude for stereoscopic surfaces

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When interpreting 3D surfaces, the human visual system is often confronted with regions with little or no structure. It has been shown that the stereoscopic system rapidly and effectively interpolates depth estimates across ambiguous regions to create the percept of a continuous plane. In previous studies, we have found reduced estimates of perceived depth magnitude for rows of elements with smooth disparity gradients (Deas & Wilcox, 2015). Here we evaluate if such distortions are also seen for extended surfaces, and assess the extent to which the interpolation process is influenced by the coherence of disparate elements. We used stimuli comprised of sparse, randomly positioned elements whose disparity map depicted two overlapping Gaussian bumps, with laterally separated peaks, but variable amplitude and width. The Gaussians were constrained so that the peaks were aligned horizontally, and the stimulus was encircled by a textured annulus positioned on the screen plane. Two horizontal line segments, one on each side of the circle, indicated the middle of the stimulus: the region that the observers were asked to estimate. Subjects viewed the stimuli stereoscopically, and on each trial toggled between the stimulus and a response screen. On the response screen, subjects indicated the perceived height of the surface along the horizontal midline, using lines with nodes that could be adjusted vertically, effectively drawing a cross-section of the surface. We found that depth estimates were accurate in the fronto-parallel regions at the edges of the bumps, but that for all test conditions, subjects systematically and significantly underestimated depth within the region containing depth variation. The depth distortions were remarkably consistent across observers, were not influenced by the percentage of elements displaced off the surface, and appear to have been constrained by the regions of maximum surface curvature.

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26.4041 **Shape constancy in anaglyphs: Effects of angle, context and instruction**

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When asked to draw a figure from perspective, many people inadvertently draw a shape representative of the figure's physical characteristics instead. This shape constancy effect has been studied extensively, yet questions remain about which 3-dimensional contextual cues are sufficient to elicit such effects, and whether, in a fully crossed design, the variables of context, instruction and angle interact. Here, we rendered quadrilateral surfaces as skeletal outlines embedded in a cuboid polyhedron or as an isolated shape, lacking texture and shading, rotated around the viewing plane, and converted them into anaglyphs. Participants were asked to report the shapes' physical and apparent width using a 6-alternative forced choice paradigm. Twelve participants each completed 440 trials, 2 repetitions of 11 angles of rotation of 3 object widths, 2 types of instruction and 2 levels of context. Statistical analyses averaging across repetitions and object width revealed a significant three-way interaction among rotation angle, instruction, and context. Participants were equivalently accurate at low levels of rotation and when judgment and context were consistent (e.g., physical width judgments were accurate for 3-dimensional shapes). When instructed judgment and level of context were inconsistent (i.e., judging the physical width of a quadrilateral or apparent width of a cuboid), participants made increasingly large errors (i.e., regression toward the real object and toward the apparent object, respectively). Results were replicated in a second experiment using the method of adjustment to capture width judgments. Although individuals can correctly estimate both real and apparent widths across rotation angle, errors arise with rotation under conditions of inconsistent instruction and context. In addition, binocular integration is sufficient to drive the perception of three-dimensional shape and elicit shape constancy effects from anaglyphs. Future studies of artistic ability and the effects of shape constancy may build on these results and new approach to measuring shape constancy.

26.4042 **Critical contours link surface inferences with image flows**

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Three-dimensional shape can be inferred from shading and/or contours, but both problems are ill posed. Computational efforts impose priors to force a unique solution. However, psychophysical results indicate that viewers infer qualitatively similiar but not quantitatively identical shapes from shading or contours or both. The challenge is to connect shading and contour inference and find the family of related solutions. We have discovered a solution to this challenge by reformulating the problem not as an inference from images directly to surfaces, but rather as one that passes through an abstraction. At the heart of this abstraction is another fundamental question rarely addressed: how can local image information, given e.g. by image derivatives, integrate to global constructs, e.g. surface ridges. Artists achieve it intuitively with strokes; suggestive contours attempt it by presuming the surface is given. Our theory uses a geometrical-topological construct (the Morse-Smale complex). We introduce a novel shading-to-critical-contour limiting process, which identifies image regions (e.g., consecutive narrow bands of bright, dark, and bright intensity) with a distinct gradient flow signature. Curves through the flow flanked by steep gradients are the critical contours. They capture generic aspects of artists' drawings and have a physiologically-identifiable signature. Importantly, this shading-limit holds for a variety of rendering functions, from Lambertian to specular to oriented textures, so it applies to many materials. Our main mathematical result proves that the image critical contours are one-to-one with corresponding structures on (the slant of) surfaces. This is the invariance that, in turn, anchors the equivalence class of surfaces. The theory is novel in that (i) it reveals an invariance at the core of surface inferences; (ii) connects the shading, contour, and texture problems; and (iii) transitions from local to global. Psychophysical predictions follow.

26.4043 **The perception of transparency with motion parallax**

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The phenomenon of motion transparency is well known and has been extensively investigated for decades. A typical demonstration of motion transparency shows random dots moving in two directions, but the perception of depth is ambiguous. Here we find that when motion parallax is used to present planes of random dots at different depths, then this facilitates the perception of transparency and makes depth less ambiguous. The motion of random dots was synchronized to participants' head movements, to present frontoparallel overlaid surfaces at different depths, within a 28 deg circular mask. The number of overlaid planes, dot density (0.5, 1, 2, 4, 8 dots/deg2) and depth separation between the planes was varied. Four participants indicated how many planes in depth they were able to perceive. In separate trials, participants also indicated the depth of the planes using a depth matching task. A coherence noise task was also used in order to determine the percent signal dots that was necessary to perceive transparency with motion parallax. The results indicated that participants could perceive at most three simultaneous overlaid surfaces. Increasing either the number of planes or dot density had a detrimental effect on the perception of transparency. At higher dot densities, only two planes could be perceived. The results with the coherence noise task indicated that transparency could be perceived at percent signal levels comparable to those for motion without transparency. These results are similar to those found for motion transparency in which disparity was used to present planes at different depths, and suggests that the number of planes that can be perceived may be limited to at most three because of effects of attention. Moreover, depth perception was likely degraded at the highest densities because of inhibitory interactions between adjacent dots moving in opposite directions and depth averaging.

26.4044 **Seeing through transparent layers**

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Humans are good at estimating the causal changes in the visual information by perceptually dividing complex visual scenes into multiple layers, this is also true when objects are viewed through a transparent layer. For example, we can effectively drive through heavy fog or hard rain; or decide whether an object in a river is animate while fishing. In such complex scenes, changes in visual information might be due to observer motion, object motion, deformations of the transparent medium, or a combination of these. Recent research has shown that image deformations can provide information to attribute various properties to transparent layers, such as their refractive index, thickness, or transparency. However, different transparent mediums can cause similar amounts of refraction or they can be rated similarly translucent while one being more foggy. Despite our rich lexicon to describe the nature of a transparent layer, the optical and geometrical properties that identify each transparent layer class remains to be discovered. Here, we use eidolons to estimate equivalence classes for perceptually similar transparent layers. Specifically, we ask whether we could describe the specific image deformations that are interpreted as transparency in terms of the parameters of the Eidolon Factory (reach, grain, coherence; https://github.com/gestaltrevision/Eidolon). To create a stimulus space for the eidolons of a fiducial image, while keeping the coherence fixed at 1, we varied the reach and grain levels to systematically increase the amount of local disarray in an image. We asked participants ($n = 11$) to adjust the reach and grain values simultaneously so that the object in the scene looked like it is under water. Our results suggest that eidolons with higher grain values ($g > 8$) are in a perceptually equivalent class and these eidolons give an under water impression, probably due to the wave-like large local disarray.

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26.4045 **Highlight disparities contribute to perceived depth of shiny 3D surface**

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When a shiny surface is viewed binocularly, the specular highlights have different disparities than points on the surface. This study tested whether conflicting highlight disparities contribute to perception of surface shape

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when other shape cues are available. A recent study by Muryy et al (2013) found that perceived shape followed highlight disparities for mirrored surfaces, but not for surfaces with texture or shading. Is stereo information from highlights overridden by additional surface information, or is there still an influence on quantitative perceived shape? To test this, I varied the depth of specular highlights relative to a surface and measured the effect on perceived extent in depth. Subjects viewed stereo images of elliptical bumps with a flat frontal rim, with varied height and curvature, and estimated height of the bump. Surfaces had smooth shading with and without highlights, and highlights were either accurate or shifted in depth. Simulated illumination was a grid of light fixtures, which was translated and scaled to control the image position of highlights. Surfaces had either high contrast texture or very low contrast texture to vary the quality of surface disparity information. With high contrast texture, highlight disparities did not influence depth estimates. The presence of highlights produced an overall increase in perceived depth, but varying the depth of highlights had no effect. With low contrast texture, depth estimates were strongly influenced by highlight disparities. The presence of highlights improved accuracy, and varying the depth of highlights produced corresponding changes in depth estimates. The effect was the same whether the highlights were consistent or inconsistent with smooth shading. The results demonstrate that binocular highlights can influence perceived shape when other surface information is available but weak. This suggests that highlight disparities are perceptually integrated despite providing conflicting information

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26.4046 **Non-veridical Depth Perception Causes Symmetric 3D Objects to Appear Asymmetric, and Vice Versa**

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Prior research has indicated that perceived depth from binocular disparity becomes increasingly compressed as viewing distance increases. One geometric consequence of this is that a symmetric 3D object should be perceived as asymmetric whenever the axis of compression is at an oblique angle to the plane of 3D symmetry. Method: To test this hypothesis, we presented binocular images of 3D polyhedra with one plane of mirror symmetry, similar to the stimuli of Li et al. (2011, doi:10.1167/11.4.11). On each trial, one of fifteen objects was rendered against a gray background on a LCD monitor. The 3D orientations of these objects were constrained so that the viewing direction (i.e., the Z-axis) formed an oblique angle with the object's symmetry plane, and at least five pairs of corresponding vertices were visible. Visible edges were all rendered in black, all occluded regions were removed, and polka-dot textures were mapped onto each visible face. Six observers looked at each polyhedron through LCD shutter glasses binocularly from a chin rest and pressed keys to stretch or compress the object along the Z dimension so as to make it appear as symmetrical as possible. Each observer performed 90 trials each from two viewing distances: "near" (100cm) and "far" (200cm). The dependent variable was the Z-scaling (S) required to make the object appear symmetrical. S=1 produced an object with perfect 3D symmetry, whereas deviations up or down from 1 produced increasing asymmetries. Results: For most observers, the adjustments were significantly larger than 1 and increased systematically with viewing distance. The group-averaged mean adjustment was S=1.24 (SE=0.07) and 1.61 (SE=0.18) at the near and far distances, respectively. This suggests that observers' inability to accurately scale binocular disparities can cause physically symmetric objects to appear asymmetric, and some asymmetric objects to appear symmetric.

26.4047 **Distortions of apparent 3D shape from shading caused by changes in the direction of illumination**

Makaela Nartker[1](nartker.28@osu.edu), James Todd[1], Alexander Petrov[1]; [1]The Ohio State University

A fundamental problem for the perception of 3D shape from shading is to achieve some level of constancy over variations in the pattern of illumination. The present experiment was designed to investigate how changes in the direction of illumination influence the apparent shapes of surfaces. The stimuli included 3D objects with Lambertian reflectance functions that were illuminated by rectangular area lights. The radial positions of these lights were systematically manipulated to allow five different directions of illumination. All stimuli had exactly the same bounding contours so that those contours provided no information for distinguishing the different possible surfaces. Observers judged the 3D shapes of these objects in two phases: First, they marked critical points (e.g. local depth minima, maxima, and inflection points) along a designated scan line in an image. These were then used to position control points on a spline curve located adjacent to the image, and observers adjusted the shape of that curve to match the apparent profile in depth along the designated scan line. The results revealed that parts of the surface appeared to shift slightly toward the direction of illumination, but these changes were much smaller than what would be expected based on differences in the pattern of luminance among the stimulus images. Regions of high curvature where the surface abruptly changed from flat to curved remained much more stable over changes in illumination than regions with more gradual curvature. These findings demonstrate that there is a substantial amount of illumination constancy in the perception of 3D shape from shading, but that it is not perfect. Several hypotheses are considered about how this constancy could potentially be achieved.

26.4048 **Effect of head translation and manual control on depth sign perception from motion parallax**

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Motion parallax produced during observer translation acts as a cue for perceiving relative depth. However, when information about observer translation is unavailable, the perceived sign of depth is ambiguous. This is theoretically and empirically ascertained. This study focuses on manual control, in comparison with head translation, as a cue for perceiving depth sign, since action can affect vision. Harman et al. (1999), for instance, reported that human object recognition was better when the observer could rotate the object images using a trackball rather than passive observation. In this study, an experiment was conducted to investigate the effect of manual control on reducing ambiguity of depth sign perception. For comparison, the effect of observer translation was also investigated. Stimuli were generated by a computer and presented on a CRT monitor. Four participants took part in the experiments. The displays simulated a corrugated surface in the frontoparallel plane, and it could be rotated to-and-fro around a vertical axis. In the experiment, each corrugated surface had one of two possible spatial phases (center-far/center-near). The surface structure was depicted with random dots on a black background. The stimulus change was associated with the rotation of a knob manipulated by the participant, or the lateral translation of a chin rest yoked to head translation. The axis of the knob was aligned with the axis of the stimulus rotation. The display was presented during participant manipulation or translation. Participants were forced to discriminate between center-far and center-near. Participants with head translation perceived the depth sign with almost perfect accuracy. Participants with manual control, by contrast, perceived the depth sign with around 0.75 accuracy (chance level 0.5). This suggests that reliability of visual change of outer world from head translation is higher than that from manual control in the visual system.

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26.4049 **Minimal Deformation Constrains the Perceived Height of the Stereokinetic Cone**

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The current study was conducted to examine whether the minimal deformation hypothesis can explain a stereokinetic percept. Stereokinetic stimuli are 2D configurations that lead to 3D percepts when rotated in the image plane. A rotating ellipse with an eccentric dot gives rise to the percept of a cone with defined height. The dot is perceived as the apex of the cone, which is constantly deforming except when the dot is on the minor axis of the ellipse. In the current study, the spatial relationship between the ellipse and dot varied across trials in terms of the dot's location (0^o [minor axis], 30^o, 60^o, 90^o [major axis]), the aspect ratio of the ellipse (0.6 or 0.8), and rotation speed (60^o/sec or 90^o/sec). During each trial, participants (n = 8) adjusted the length of a 2D bar to indicate their perceived height of the cone. This 2D bar was oriented along the ellipse's minor axis and was perceived to be perpendicular to the circular base of the cone. Our results were quantitatively consistent with the traditional hypothesis of minimal deformation, which is similar to the maximal rigidity assumption (Ullman, 1979). As the dot shifted position from the minor axis towards the major axis, observers consistently reported an increasingly shorter cone. The results illustrate the tendency of observers to perceive the apex of the cone at a height that minimized its distance to the axis of rotation in order to reduce the relative motion between the dot and circular base of the cone. Therefore, the hypothesis can also be considered as a 3D extension of the more recent "slow and smooth" hypothesis (Yuille & Grzywacz, 1988; Weiss, Simoncelli, & Adelson, 2002).

26.4050 Mapping the Hierarchical Neural Network of 3D Vision using Diffusion Tensor Imaging

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The transformation of egocentrically encoded two-dimensional (2D) retinal images into allocentric three-dimensional (3D) visual perception is essential for successful interactions with the environment. However, the hierarchical neural network underlying this transformation remains largely unknown. Here we use diffusion magnetic resonance imaging (GE MR750 3T scanner, 16-channel receive-only head coil; 60 diffusion directions, b=1000 s/mm 2 , NEX=10) to map the neural network of 3D vision in rhesus macaques (N=7). Focus is given to the caudal intraparietal area (CIP), an important site of 3D visual processing, as well as the visual posterior sylvian area (VPS) which is implicated in allocentric vision. T1-weighted scans are first used to define cortical areas according to the F99 atlas using CARET software. High-resolution diffusion-weighted scans (1mm isotropic) are then used to perform probabilistic tractography using FSL. Our results reveal a network within the dorsal visual pathway that putatively underlies 3D vision. Consistent with previous anatomical data, we find that V3A is strongly connected with CIP. We further find that the posterior intraparietal area (PIP) likely contributes to the 2D to 3D visual transformation as an intermediate stage between V3A and CIP. Additionally, we provide the first evidence that CIP is connected with the retroinsular cortex (Ri), a subdivision of VPS where visual responses are observed. By combining our probabilistic tractography results with previous electrophysiological and anatomical data, we propose that the following circuit underlies the 2D to 3D visual transformation and creation of allocentric visual representations: V1 → V2d → V3A → PIP → CIP → Ri. To elucidate a broader neural network underlying 3D visual perception and action, future work will extend this analysis to include the ventral visual pathway, as well as decision and motor circuits. We are additionally using these results to guide electrophysiological studies investigating the neural basis of 3D visual perception.

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26.4051 Overrepresentation of vertical limbs in primate inferotemporal cortex

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We reported previously that responses of individual neurons in macaque monkey inferotemporal cortex (IT) convey information about 3D medial axis shape (Hung et al., Neuron, 2012). Specifically, many IT neurons signal configurations of medial axis elements (connected torsos and limbs) in terms of 3D position, orientation, curvature, and connectivity. We hypothesized that these neurons provide an explicit, efficient shape code for elongated, branching objects such as vertebrate animals. Here, we analyzed the strength of IT neural population responses to projecting limbs (medial axis elements that have a termination on one end). Our dataset comprised spiking responses of 111 IT neurons, each tested with 400–600 3D medial axis shapes presented on a computer monitor using shading and binocular disparity as cues for shape-in-depth. These shapes were initially random but evolved through multiple generations based on a genetic algorithm driven by the neuron's responses. Thus, our sampling strategy converged toward high response shapes in later generations. We characterized projecting limbs in terms of their object-centered 3D position, 3D orientation, curvature, and surface shape. We binned the position/orientation/curvature/surface space into a multi-dimensional matrix. For each stimulus, we summed the neural response into the bins occupied by that stimulus. We used plots and statistical tests to analyze anisotropies in the resulting matrix. One major trend was over-representation of vertical limbs, that is, limbs projecting downwards or upwards. We hypothesize that this over-representation of vertical limbs reflects the prevalence and/or ecological significance of vertical projections in the natural world.

26.4052 Perception of Depth in Natural Scenes

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The role of disparity in depth perception has typically been studied using random-dot stereograms because they contain no monocular clues, thus isolating the responses to "pure disparity". Pure disparity rarely exists in the real world. Rather, disparity occurs in the context of several monocular depth cues. To study disparity processing in natural scenes, we compared visually evoked responses to 2D and 3D versions of the same scene that differed only in their disparity structure. Thirty natural scenes were drawn from a large set of natural image stereo-pairs (Burge et al., 2016 J. Vis) to ensure diversity of scene types and depth maps. The scenes mainly included outdoor settings with trees and buildings. Nineteen subjects (Mean age = 22.9, 8 males) viewed a sequential two-alternative temporal forced choice presentation of two different versions of the same scene (2D vs. 3D) interleaved by a scrambled image with the same power spectrum (4 images per trial, 750 ms each). Scenes were viewed orthostereoscopically at 3 meters through a pair of shutter glasses. After each trial, participants indicated with a key press which version of the scene was 3D. Performance on the discrimination was >90%. We compared 128 channel Visual Evoked Potentials elicited by 2D and 3D scenes using Reliable Component Analysis (Dmochowski Greaves and Norcia, 2015). Both scene types elicited responses with onset times of ~180 msec. The differential response between 2D and 3D scenes was maximal on mid-line electrodes over the occipital pole. Significant differences between responses to 2D and 3D scenes first emerged at around 200 msec. This suggests that approximately 20 additional msec are needed for the brain to begin the extraction of 3D structure from the disparity cues in natural scenes.

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26.4053 Learning to identify depth edges in real-world images with 3D ground truth

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Luminance edges in an image are produced by diverse causes: change in depth, surface orientation, reflectance or illumination. Discriminating between these causes is a key step in visual processing, supporting segmentation and object recognition. Previous work has shown that humans can discriminate depth from non-depth edges based on a relatively small visual region around the edge (Vilankar et al. 2014), however little is known about the visual cues involved in this discrimination. Attempts to address this question have been based upon small and potentially biased hand-labelled datasets. Here we employ the new Southampton-York Natural Scenes (SYNS) 3D dataset (Adams et al. 2016) to construct a larger and more objective ground truth dataset for edge classification and train a deep network to discriminate depth edges from other kinds of edges. We used a standard computer vision edge detector to identify visible luminance edges in the HDR images and fit planar surfaces to the 3D points on either side of the edge. Based on these planar fits we classified each edge as depth or non-depth. We trained convolutional neural networks on a subset of SYNS scenes to discriminate between these two classes based only on the information in contrast-normalized image patches centred on each edge. We found that the networks were able to discriminate depth edges in a reserved test subset of the SYNS scenes with 81% accuracy. Interestingly, this performance was relatively invariant with patch size. Although performance decreased when information about edge orientation or color was removed, it remained in the 72-75% range, suggesting a larger role for spatial (e.g., blur, textural, configural) cues. These results demonstrate that 1) The SYNS dataset can be used to provide 3D ground truth for visual tasks, and 2) Colour, orientation and spatial cues are all important for the local discrimination of depth edges.

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26.4054 Mitigating Perceptual Error in Synthetic Animatronics using Visual Feature Flow

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The perceived visual flow of features on a 3D object provides cues about the underlying shape and motion. Likewise, imagery of a dynamic virtual object projected onto a static featureless physical object can be used to simulate shape or motion. If the shape of the virtual object is geometrically different from the physical object, the visual flow of features moving across the surface will be distorted, conveying incorrect shape cues. Mitigating these incorrect shape cues supports synthetic animatronics—simulating physical motion or deformation on geometrically static display surfaces. To achieve this, we define two sets of feature flow curves that represent the visual flow of a set of features over the course of an animation for a specific viewpoint: one set of features for the flow corresponding to the correct perception of the virtual object, and a second for the flow of features otherwise distorted by the display surface. These feature flow curves provide a basis for a perceptual error measure at single time steps (e.g., visual angular error) and for identifying temporal flow patterns that might give perceptual shape cues for the underlying display surface (e.g., a sharp trajectory change indicative of a fold or edge). We then dynamically alter the virtual imagery on the physical surface to reduce perceptual error by diminishing the visibility of specific features (and thus the resulting visual flow). This is achieved by contrast reduction or low-pass filtering proportional to the aggregate error across a set of viewpoints. We have observed that by doing this dynamic filtering of the virtual imagery we can reduce the unwanted perception of the underlying surface while maintaining feature salience in areas of geometric similarity, upholding the overall perception of the desired virtual shape and motion.

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VISUAL MEMORY: NEURAL MECHANISMS

Saturday, May 20, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4055 Spatial selectivity of alpha band activity declines with increasing visual working memory load

David Sutterer[1](sutterer@uchicago.edu), Joshua Foster[1], Kirsten Adam[1], Edward Vogel[1], Edward Awh[1]; [1]University of Chicago

Recent work has demonstrated that it is possible to reconstruct spatially-specific channel tuning functions (CTFs) during the encoding and delay period of a working memory (WM) task, using an inverted encoding model (IEM) and electroencephalography (Foster et al., 2016). These CTFs can be derived from the distribution of alpha-band (8-12hz) activity across the scalp, providing a temporally resolved measure of the location of a single position stored in WM. Recent, functional magnetic imaging (fMRI) work has demonstrated that feature specific patterns of bold activity degrade as memory load increases (e.g. Sprague, Ester, and Serences, 2014). Here, we show that the loss of feature specificity with increasing memory load extends to spatially specific patterns of alpha band activity. On each trial, participants encoded and maintained the location of either one or two colored dots while EEG was recorded. After a 1s delay period, participants were cued to report the location of one of the dots. We trained an IEM to assess CTF selectivity for each set-size and found that CTF selectivity decreased when participants maintained two items relative to a single item, consistent with behavioral performance decrements observed with memory load increases. A key debate is whether items are maintained simultaneously (each with lower precision), or if instead only a single item is actively represented at any given time-point (i.e. shifting 1-item focus of attention), but previous fMRI work lacked the temporal resolution to address this question. Simulations revealed that CTF selectivity was significantly higher for the observed two-item activity than would be expected if subjects only actively maintained one of the two items, suggesting that participants simultaneously represented two positions. Together this pattern of results supports the idea that oscillatory activity in the alpha band is integral to online spatial representations during memory maintenance.

26.4056 Topography of alpha-band power tracks improvement in working memory precision with repeated encoding

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The topography of EEG alpha-band power (8 – 12 Hz) tracks locations held in visual working memory in a time-resolved fashion (Foster et al. 2016). However, there has been little work linking changes in the quality of alpha-band representations with changes in behavioral precision. In two experiments, we tracked changes in behavioral precision and EEG alpha-band representations as memoranda were repeated across trials. In Experiment 1 (n = 16), participants performed a 1-item spatial working memory task. During each trial, participants remembered a briefly presented spatial location (100 ms) over a blank delay (1,000 ms) and reported the remembered location using a mouse click. The same memory display was repeated six trials in a row. In Experiment 2 (n = 23), participants performed a 1- or 2-item spatial working memory task, and each display repeated three times. In both experiments, behavioral precision improved for repeated displays relative to novel displays, and the quality of alpha-band representations likewise improved. Previously, it has been demonstrated that alpha-band representations track memory content independent from response preparation; thus, the observed changes in the quality of alpha-band representations rule out simple motor priming accounts of improvement across repetitions. These data also demonstrate that decoded alpha-band representations are sensitive to subtle improvements in the quality of working memory representations (here, an average response error improvement of only around 1 degree). Finally, we observed that participants continued to attend to the previously remembered location (as measured by the presence of alpha-band representations) during the inter-trial interval, suggesting that the behavioral boost for repeated stimuli came from covertly attending relevant locations at the time of encoding.

Acknowledgement: NIH 2R01 MH087214-06A1

26.4057 Working memory reconstructions using alpha-band activity are disrupted by sensory input.

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Recent work suggests that the spatial distribution of alpha-band activity across the scalp measured by electroencephalography (EEG) can be used to track specific spatial representations of stimuli held in working memory (WM; Foster et al. 2016). Here, we tested the extent to which these representations can be disrupted by sensory input. Participants (n=18) performed a simple recall task involving the presentation of a circular stimulus (250ms) at one of eight equally spaced locations circumventing fixation and the subsequent recall of the stimulus location following a brief retention period (1750ms). Critically, we manipulated the representation of the stimulus during the retention period by 1) requiring participants to close their eyes immediately after stimulus offset and 2) presenting a mask immediately after stimulus offset. Requiring participants to close their eyes eliminated the potential for continued spatial selection during the retention period, and masking reduced possible after-image effects. Participants engaged in four conditions while we recorded EEG at the scalp: eyes-open, eyes-closed, eyes-open/masked, eyes-closed/masked. We used an inverted encoding modeling technique to estimate location-selective tuning functions (TFs) from spatially distributed alpha activity measured across the scalp during the target and retention period (Foster et al. 2016). We then folded these TFs at center and calculated slope at each time-point. We observed a robust stimulus representation (greater positive slope) during the stimulus presentation, followed by a decline in the quality of the representation during the 500ms post-stimulus offset. Between 200-500ms post-stimulus the mask caused significant disruption to the spatial representation of the stimulus, relative to the unmasked conditions ($p < .05$). Furthermore, the stimulus representation was not reliable in the eyes-closed/masked condition during the final 1000 ms of the retention period ($p < .05$), and WM precision was reduced ($p < .05$). Together, these effects suggest alpha-band WM representations are not immune to disruption by sensory input.

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26.4058 Alpha-band activity reveals robust representations of spatial position during the storage of non-spatial features in working memory

Joshua Foster[1](joshuafoster@uchicago.edu), Emma Bsales[1], Edward Awh[1]; [1]Department of Psychology, The University of Chicago

Saturday PM

Visual working memory (WM) enables active maintenance of visual information via sustained patterns of stimulus-specific activity (Harrison & Tong, 2009; Serences et al., 2009). Past work has shown that observers can control which features of an object are maintained in WM (Serences et al., 2009; Woodman & Vogel, 2008). However, behavioral studies suggest that stimulus position enjoys a privileged status in WM (e.g., Rajsic & Wilson, 2014), raising the possibility that unlike non-spatial features, stimulus position may be necessarily maintained alongside to-be-remembered features. To test whether stimulus position is maintained during non-spatial WM tasks, we examined spatially selective alpha-band (8-12 Hz) activity using an encoding model of spatial selectivity. Using this approach, past work has shown that the scalp distribution of alpha-band activity tracks locations stored in WM (Foster et al., 2016). In Experiment 1, observers remembered the color of a sample stimulus. While the position of the sample stimulus varied trial-to-trial, stimulus position was irrelevant to the task and unpredictive of probe position. Nevertheless, alpha activity tracked the original location of the stimulus throughout the delay period, demonstrating that stimulus position was represented in the pattern of alpha-band activity. Experiment 2 established that these spatial representations are under volitional control rather than being an automatic consequence of sensory activity – when observers were asked to store one of two simultaneous presented sample stimuli, spatially selective alpha activity was amplified for the target item compared to the non-target item. In Experiment 3, we observed spatially selective activity throughout the delay period of an orientation WM task, suggesting that spatial representations are not specific to the storage of colors in WM but are seen during the storage of non-spatial features in WM more generally. Our findings show that active representations of stimulus position are retained during the maintenance of non-spatial features in WM.

26.4059 **Parieto-occipital alpha power dynamics selectively code for the storage of spatial locations in visual working memory** Keisuke Fukuda[1](keisuke.fukuda@utoronto.ca), Christopher Sundby[2,3], Geoffrey Woodman[2]; [1]Department of Psychology, University of Toronto Mississauga, [2]Department of Psychology, Vanderbilt Vision Research Center, Vanderbilt University, [3]Department of Law, Vanderbilt University

Visual working memory (VWM) allows us to actively represent a limited amount of visual information in mind at a given moment. Recent electrophysiological studies have consistently shown that modulations of the power of parieto-occipital alpha activity (8-13Hz) is directly involved in active maintenance of VWM representations. For example, the reduction of the parieto-occipital alpha power observed during the VWM retention interval shows the capacity-limited set size effect predicted by the behavioral measures of VWM capacity (Erikson, et al., 2016; Fukuda, Mance, & Vogel, 2015; Fukuda, Kang, & Woodman, 2016). Furthermore, the topographical distribution of this alpha power modulation during VWM delay can be used to decode the content of VWM (Foster, et al., 2016; Fukuda, Kang, & Woodman, 2016; Samaha, Sprague, & Postle, 2016). In this study, we sought to extend this finding by specifying the nature of the representation in VWM that are reflected in these parieto-occipital alpha power dynamics. More specifically, we had participants maintain location, color, or their conjunction in a short-term memory task while we recorded their electroencephalograms (EEGs). Pattern classification results revealed that location information, but not color information, can be reliably decoded from the topographical distribution of the parieto-occipital alpha power during the retention interval of the memory task. This finding clearly demonstrates the selective sensitivity of the parieto-occipital alpha activity to the storage of spatial locations in VWM.

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26.4060 **Alpha-Band Activity Tracks Updates to the Content of Spatial Working Memory** Eren Gunseli[1](gunseli.eren@gmail.com), Joshua Foster[1], David Sutterer[1], Edward Vogel[1], Edward Awh[1]; [1]Department of Psychology, Institute for Mind and Biology, University of Chicago

Prior work has shown that topography of alpha-band activity tracks locations maintained in spatial working memory (WM). Here, we tested whether dynamic changes in alpha activity track the updating of information in spatial WM. Subjects were shown a memory location followed by an auditory cue which instructed subjects to update the location held in memory. Subjects used the mouse to click on the updated location. We used an inverted spatial encoding model to reconstruct the spatially-selective response profiles from the topographic distribution of alpha power. This time-resolved analysis showed that spatially-specific alpha activity tracked the initial location held in working memory, and revealed the transition to the newly updated location. Furthermore, the location specificity of the estimated response profiles, or Channel Tuning Functions (CTFs), showed that subjects with a stronger focus on the updated location were faster to report that location at the end of the trial. These findings highlight a new approach for observing active updating of the contents of spatial WM.

26.4061 **Suppression of irrelevant information from working memory is reflected in the PD and CDAp components of the EEG** Tobias Feldmann-Wüstefeld[1](tobiasfw@uchicago.edu), Edward Vogel[1]; [1]University of Chicago

Visual Working Memory (WM) literature has traditionally focused on how the visual system maintains relevant information. On the other hand, visual attention studies demonstrated the crucial role of active suppression. Given the close relationship between visual WM and visual attention, it stands to reason that active suppression plays an important, and yet often ignored, role in WM. To better characterize this, we adapted a classical change detection task (Luck & Vogel, 1997) to include irrelevant information. In this task, participants were simultaneously presented with items that were to-be-memorized (memory targets) and to-be-ignored items (memory distractors). Critically, memory targets and distractors were systematically lateralized, enabling us to use lateralized ERP components to isolate the neural markers of suppression from WM. Specifically, we were interested in an N2pc subcomponent, the distractor positivity (PD). The PD is typically observed in visual search tasks in which salient items need to be actively suppressed (Hickey et al., 2009). We hypothesized that this ERP component would also be implicated in this WM task given that active suppression was required. We found that the PD component increased with the number of distractors to be suppressed from WM, with the WM capacity being identical. This suggests that in order to sufficiently maintain relevant information in WM, more active suppression was required with an increasing number of irrelevant items. Furthermore, individual differences in WM capacity predicted the PD amplitude. This demonstrates that the ability to suppress irrelevant information from WM contributes to better WM performance. In addition we found contralateral delay activity of positive polarity (CDAp) starting at around 450 ms, suggesting lingering active suppression of irrelevant items from WM. In sum our results suggest that active suppression of irrelevant information plays an important role in visual WM and its neural markers are the ERP components PD and CDAp.

26.4062 **What Information Can Actually Be Decoded from the EEG in Visual Working Memory Tasks?** GiYeul Bae[1](freebird71@gmail.com), Steven Luck[1]; [1]Center for Mind and Brain, University of California, Davis

Previous research showed that a feature value stored in memory (WM) can be decoded via a spatial pattern of EEG oscillatory activity in the EEG alpha band (8-12 Hz). The present study sought to determine what information is actually being decoded. First, we asked whether orientation can be decoded when it is decoupled from location. In Experiment 1, observers performed an orientation delayed estimation task in which the orientation and the angular location of a sample stimulus were independently manipulated. We separately decoded both the orientation and the angular location. We found that pure orientation decoding was above chance, although it was considerably weaker than pure location decoding. Second, we investigated how precisely angular location information can be decoded. Decoding precision was computed by estimating the dispersion of the decoded response distributions, and we also compared decoding performance using different numbers of underlying channel tuning functions (CTFs). We found that the decoding precision reaches at asymptote at 8 CTFs, implying that the EEG can discriminate angular locations as small as 45 degrees of the angular space. Third, we found that the decoding was equally precise across different feature values and that it reflects both metric and categorical information. Fourth, we found that decoding is above chance when the decoding weights derived from one observer are applied to another observer, indicating some consistency in scalp topography. Fifth, by temporally separating data for training and testing, we found that the EEG codes both time-dependent and time-independent information. Lastly, using a 2AFC task, Experiment 2 showed that orientation decoding can be achieved using a task other than delayed estimation. Together, these findings provide several insights about what visual information is actively maintained in working memory and can be decoded from the EEG.

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26.4063 Decoding the Contents of Working Memory Using EEG Provides Evidence For the Sensory Recruitment Hypothesis Allison Bruning[1](alb835@msstate.edu), Michael Pratte[1]; [1]Department of Psychology, Mississippi State University

Recent fMRI studies have shown that the contents of visual working memory can be decoded from early visual areas, including V1. This result has been interpreted as support for the sensory recruitment hypothesis: the idea that the neurons responsible for vision also sub-serve visual working memory and visual imagery. However, whereas these results imply that the same brain areas are responsible for vision and visual memory, they do not rule out the possibility that these processes rely on completely different populations of neurons within these areas. For example, although viewing and remembering an orientation might lead to the same global radial bias pattern in V1, entirely different neurons may produce these patterns during vision and memory. We develop a novel EEG paradigm that allows us to directly test whether the same neurons responsible for processing incoming visual signals are indeed modulated by an internally driven memory signal. Participants held an orientation in working memory while viewing a flicking visual noise patch. This flickering stimulus generated an EEG response known as the steady state visually evoked potential (SSVEP), a measure of early neural responses to the noise stimulus. Critically, if memory relies on these same visual neurons, then the SSVEP response to visual stimulation should also carry information about the stimulus being held in memory. We confirm this prediction by showing that a multivariate pattern classifier can be used to identify a remembered orientation from the stimulus-driven SSVEP. This finding demonstrates a direct interaction between a bottom-up stimulus-driven signal and a top-down memory-driven signal, providing strong evidence for the sensory recruitment hypothesis and a powerful new approach for investigating visual memory with EEG.

26.4064 Bridging Working Memory and Imagery: Encoding induced alpha EEG activity reveals similar neural processes Joel Robitaille[1](jrobitaille089@gmail.com), Stephen Emrich[1]; [1]Psychology Department, Brock University

While both imagery and visual working memory address the mental representation of visual information, it remains unclear whether the representations of information during these processes are mediated by similar mechanisms. Albers et al. (2012) were able to demonstrate that working memory representations can be identified and tracked down during a mental imagery rotation by decoding fMRI activity detected in the primary visual cortex. A recent study by Foster et al. (2016) reported that it is possible to identify the feature of an object held in working memory by applying an encoding model on induced alpha activity (8-15Hz). In an attempt to determine the similarities between imagery and working memory, we replicated Foster et al. (2016) and extended their findings by investigating the behavioural and neural properties imagery. A forward encoding model was applied to EEG activity recorded while participants were holding the orientation of a stimulus in working memory and then transformed through a mental rotation of 60°. The reconstruction of orientation selectivity profiles revealed the orientation of the working memory representation and reliable changes in the mental representation during the imagery manipulation. Furthermore, the behavioural results indicate that the level of precision in the report of the transformed orientation feature is comparable with typical working memory precision. These results suggest that visual working memory and imagery share similar neural and behavioural mechanisms.

Acknowledgement: NSERC

26.4065 Time-reversed activation of sequentially memorized items during maintaining period in humans Qiaoli Huang[1,2](1601110612@pku.edu.cn), Jiarong Jia[1,2,3], Huan Luo[1,2]; [1]School of Psychological and Cognitive Science, Peking University, [2]IDG/McGovern Institute for Brain Research, Peking University, [3]Peking-Tsinghua Center for Life Science, Peking University

It has been hotly debated whether multiple items in working memory are represented simultaneously or sequentially. A recent study found that items in different sequence positions elicited gamma power that is phase locked to distinct phase of a theta oscillation, supporting the sequential representation model. However, the results are based on activities in encoding period and it still remains unknown how the sequentially memorized items are represented during maintaining period. In the present study, we recorded EEG activities while human subjects performed a sequential working memory task. In each trial, subjects were first presented with multiple rectangles with different orientation and color, and were instructed to only memorize the orientation of the cued rectangles and their temporal order ("Encoding phase"). Next, they performed a central fixation task, and were simultaneously presented with circles either endowed with memory-related color or memory-unrelated color ("Maintaining phase"). Finally, they were asked to judge whether or not the orientation of a presented rectangle was similar to that of the to-be-memorized rectangles in the Encoding phase ("Recalling phase"). Critically, we employed a temporal response function technique (TRF) to extract item-specific response in "Maintaining phase". We found that first, the TRF responses for the to-be-memorized items exhibited stronger alpha-band (~10 Hz) power compared to non-memorized item. Second, the alpha power profiles for the multiple to-be-memorized items showed a time-reversed alpha activation pattern. Specifically, the item that occupied earlier (later) sequential position in Encoding phase elicited later (earlier) alpha responses in Maintaining period. Finally, the sequential activation sequence became faster as the memory list became longer. In summary, our results support the sequential representation model in working memory, and provide direct neuronal evidence in human subjects that sequential memory is mediated by re-activating sequences in a time-reversed manner during maintaining period.

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26.4066 Modulation of working memory filtering efficiency during acute bouts of exercise. Lindsey Purpura[1,2](lindsey.purpura@psych.ucsb.edu), Thomas Bullock[1,2], Barry Giesbrecht[1,2]; [1]University of California, Santa Barbara, [2]Institute for Collaborative Biotechnologies

Locomotor activity impacts behavioral performance and brain activity in various species including invertebrates, rodents, and humans (Chiappe et al., 2010; Niell & Stryker, 2010; Bullock et al., 2015; Bullock et al., 2016). Here we investigated the effect of exercise on working memory (WM) filtering efficiency. Filtering efficiency was measured using the amplitude of the scalp-recorded contralateral delay activity (CDA). CDA amplitude tracks with the number of encoded items and can be used as a way to assess the amount of encoded information compared to the number of relevant and irrelevant items presented (Vogel et al., 2005). While previous research suggests sensory gain during exercise (Bullock et al., 2015), other work suggests impaired cognitive control during physical exertion (Eddy et al., 2015). If filtering efficiency is related to attentional control, then the finding that cognitive control is impaired during physical exercise predicts decreased filtering efficiency during exercise. To test this prediction, participants (n=5) encoded a brief (100 ms) memory array and after a retention period (900ms) reported if any relevant items had changed orientation. One-third of trials included four relevant items, one-third presented two relevant items, and one-third presented two relevant and two irrelevant items. Participants completed this task during rest (mean heart rate (HR)=67.3 bpm) and low intensity (duration = 45 min; mean HR=103.7 bpm) cycling. Filtering efficiency was calculated for each subject and each exercise condition. Filtering efficiency was higher during rest compared to low intensity exercise, $t(4)=2.31$, $p< .05$ (one-tailed). All participants showed this effect. Although it is unclear whether this effect is caused by a drop in CDA amplitude for four relevant items or an increase in amplitude on trials with irrelevant items during low intensity exercise compared to rest, the results suggest that WM filtering efficiency is modulated by brief bouts of physical exercise.

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26.4067 Neural evidence for unitization following perceptual expertise Jackson Liang[1](jacksoncliang@gmail.com), Jonathan Erez[2], Felicia Zhang[3], Rhodri Cusack[2,4], Morgan Barense[1,5]; [1]Department of Psychology, University of Toronto, [2]Department of Psychology, University of Western Ontario, [3]Department of Psychology, Princeton University, [4]The Brain and Mind Institute, [5]Rotman Research Institute

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The organization of representations in the ventral visual stream (VVS) is thought to be hierarchical, such that posterior VVS represents simple object features, whereas anterior VVS supports increasingly complex conjunctive representations of multiple features. Despite considerable empirical support for this representational hierarchy for processing novel objects, it is unclear what changes occur to distributed object representations with extended learning. The perceptual expertise literature shows that discrimination between complex objects becomes faster with experience; this is a hallmark of unitization theory, whereby multiple features can be unitized and accessed as rapidly as a single feature. Keeping the organizing principle of the representational hierarchy in mind, this simple idea makes a powerful and unique prediction: unitization through perceptual training should modify conjunctive representations, but not simply as response tuning of existing representations. Rather, conjunctive representations would be redistributed to posterior VVS, whose architecture is specialized for processing single features. To test this hypothesis, we used fMRI to scan participants before and after visual training with novel objects comprising 1-3 features that were organized into distinct feature conjunctions. First, we used neural pattern similarity to replicate earlier findings that complex feature conjunctions were associated with conjunctive coding in anterior VVS. Critically, we also demonstrated that for well-learned objects, the strength of conjunctive coding increased post-training within posterior VVS. Furthermore, multidimensional scaling revealed increased pattern separation of the representation for individual objects following training. Finally, we showed that functional connectivity between anterior and posterior VVS increased for unfamiliar objects, consistent with early involvement in unitizing feature conjunctions in response to novelty. While there is strong behavioral support for unitization theory, a compelling neural mechanism had been lacking to date. Here, we leveraged recent advances in VVS subregional function to link established behavioral observations with representational transformations in the human brain.

26.4068 Neural mechanisms of precision in visual working memory for faces

Elizabeth Lorenc[1](elizabeth.lorenc@berkeley.edu), Mark D'Esposito[1,2]; [1]Helen Wills Neuroscience Institute, University of California, Berkeley, [2]Psychology, University of California, Berkeley

Visual working memory (VWM) allows for the maintenance and manipulation of information about objects no longer in view. Interestingly, the precision with which visual information can be encoded, maintained, and retrieved from VWM varies considerably between healthy individuals, and even from trial to trial within a single individual. We hypothesize that a stimulus-selective area such as the fusiform face area (FFA) supports precise VWM by maintaining perception-related activity when a visual stimulus is no longer present. To that end, we trained an encoding model on perception-related activity patterns, and then inverted the model to reconstruct face VWM representations in the FFA and early visual areas. Functional magnetic resonance imaging data was collected while participants performed a delayed-estimation task for faces. On each trial, a post-cue indicated whether the participant should store the item through a 10s delay period ('Store") or discard it from memory ("Drop"). "Store" trials ended with a method-of-adjustment response in which a random face was morphed to match the remembered face, and "drop" trials ended with a perceptual matching task in which a probe face was morphed to match a simultaneously-presented test face. We found that faces could reliably be reconstructed from both the early visual and FFA regions of interest during perception, before the "store" or "drop" post-cue. Interestingly, reliable face reconstructions persisted in both V1-V3 and the FFA through the memory delay, when a participant was actively holding a face in memory. However, we found the opposite in the "drop" trials; delay activity patterns were anti-correlated with those at perception, yielding negative population tuning curves. Future analyses will investigate the role of the lateral prefrontal cortex in sustaining perception-related activity when a face stimulus is actively maintained in working memory, and in suppressing that activity when maintenance is not required.

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26.4069 Decoding visual spatial working memory uncertainty from human cortex

Thomas Sprague[1](tsprague@nyu.edu), Masih Rahmati[1], Aspen Yoo[1], Wei Ji Ma[1,2], Clayton Curtis[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Although we have remarkable insight into the variations in quality of our visual working memory (WM) representations (Rademaker et al, 2012), how this uncertainty arises from neural activity patterns remains unknown. Bayesian theories of probabilistic population coding posit that information is represented as a probability distribution over feature values within populations of noisy neurons, and that the width of distributions directly indexes the uncertainty with which a feature is represented (Pouget et al, 2000; Ma et al, 2006; Jazayeri & Shadlen, 2006). Previous efforts to relate behavioral performance to neural WM representations (Ester et al, 2013; Sprague et al, 2014; 2016) have used linear methods, which cannot utilize the noise in neural responses to optimally constrain decoding. This is a critical challenge, as noise places critical constraints on representations of information in neural activity patterns (Averbeck et al, 2006). Here, we adapted a recently-published decoding method to measure representations of spatial positions in WM, as well as their uncertainty (van Bergen et al, 2016). This method, based on a Bayesian generative model of neural activity which incorporates spatial preferences of individual voxels and estimates of their noise, results in a full likelihood function over feature values, rather than a point estimate. Participants remembered a precise spatial position over an extended delay interval (10 s) while we imaged cortical activation patterns using BOLD fMRI. Decoded likelihood functions from visual cortex yielded accurate estimates of decoded feature values (mean of the likelihood function). Furthermore, the uncertainty of feature representations (circular standard deviation of the likelihood function) accurately reflected the noise of the representation: on trials with greater uncertainty, decoding error was higher. These results support variable precision models of WM, which posit that items are maintained with different levels of precision across items and across trials (van den Berg et al, 2012).

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26.4070 Active Maintenance of Working Memory Representations Remains Robust Under Automatic, But Not Non-Automatic, Processing of Distractor Stimuli

Orestis Papaioannou[1,2](orpapa@ucdavis.edu), Steven Luck[1,2]; [1]Center for Mind and Brain, UC Davis, [2]Department of Psychology, UC Davis

Visual working memory relies heavily on the active maintenance of representations. However, it is unclear whether this active maintenance can co-occur with other concurrent processing of stimuli. Sparked by this question, we used event related potentials (ERPs) - specifically contralateral delay activity (CDA) - to create a continuous marker of active maintenance of lateralized stimuli during the processing of lexical stimuli. Participants were asked to remember four colored items presented on the right or left side of the screen for a change detection task. A lexical item (word or consonant string) was presented during the 1500 ms retention interval on a subset of trials. Participants were instructed to either ignore these items and focus entirely on the memory task (single-task condition), or to indicate whether the item presented was a word or consonant string (dual-task condition). A CDA to the lateralized memory items was observed for both conditions prior to, or in the absence of, an intervening stimulus. However, the CDA was disrupted by the processing of the lexical items during the duals task condition, but not the single task condition. A larger N400 - a component associated with semantic and orthographic processing - was found for words compared to consonant strings in both conditions, indicating that participants differentiated between words and consonant strings in both conditions. Thus, during the single-task condition, the CDA was not disrupted by the lexical stimuli even though the N400 data indicate that these stimuli were discriminated. Taken together, these finding suggest that active maintenance is unimpeded by automatic lexical processing but fails when this same processing must be tied to a non-automated task. Interestingly, behavioral measures show only a minor decrease in change-detection performance in the dual-task condition, providing evidence of a secondary working memory process that can support the memory task when the CDA has been disrupted.

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26.4071 Decoding the Content of Visual Working Memory in the Human Visual System

Xilin Zhang[1](xilin.zhang@nih.gov), Nicole Mlynaryk[1], Shruti Japee[1], Leslie Ungerleider[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health, National Institutes of Health, Bethesda, Maryland, USA

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Visual working memory (VWM) enables the storage and manipulation of limited information about stimuli no longer in view over short temporal intervals. Given the huge amount of information confronting the visual system at any given moment, VWM storage of multiple items is often required. However, how multiple VWM representations are maintained in the human visual system remains unclear. Here, we used functional magnetic resonance imaging (fMRI) multivariate pattern analysis (MVPA) to address this question as human subjects performed a delayed orientation discrimination task. During each trial, subjects maintained fixation while three sample orientation gratings (20° ± 3°, 80° ± 3°and 140° ± 3°) were randomly presented in three locations (5° eccentricity) for 3 s, followed by a cue indicating the number of gratings (i.e., the memory load: R1, R2, and R3) that subjects needed to remember (one, two, and three gratings, respectively). These three types of cue appeared with equal probability and randomly in the experiment. After a 10-s retention interval, a test grating was briefly and randomly presented in one of the cued locations, and subjects indicated its orientation relative to the cued grating (± 3° or ± 6°). Behavioral data showed that the increasing memory load (R1, R2, and R3) impaired subjects` performance in discriminating the small differences in orientation between the cued grating and the test grating. The fMRI experiment demonstrated that MVPA decoding in occipital areas, but not parietal areas, closely tracked the impaired subjects` performance along with the increasing memory load (R1, R2, and R3). Our results suggest that occipital cortex, but not parietal cortex, has a central role in multiple VWM storages in the human brain.

26.4072 **Can the visual cortex represent the invisible?** Shude Zhu[1](zhushude@gmail.com), Li Zhang[1], Rudiger von der Heydt[1,2]; [1]Krieger Mind/Brain Institute, Johns Hopkins University, [2]Department of Neuroscience, Johns Hopkins School of Medicine

In everyday vision objects often occlude others from sight, but objects are perceived as permanent despite temporary occlusions. Observations on border ownership coding in low-level visual areas (V1, V2) suggested an influence from object representations at a higher level that have some persistence (O'Herron & von der Heydt, JOV 11(2):12, 2011). We recorded from neurons of areas V2 and V4 searching for persistence of object-evoked activity during temporary occlusion. Monkeys performed a visual foraging task in which they sequentially fixated individual figures of an array of 10 figures in search for reward. The array was constructed so that fixating one figure would, in most cases, bring another figure into the receptive field (RF) of the neuron under study, while in other cases it would bring uniform background into the RF. During the presentation of the array, a grating of opaque stripes drifted over the array, variably occluding some of the figures. To a human observer, the 10 figures appeared permanent despite the temporary occlusions. The fixations produced 4 different conditions, depending on whether the RF was on an occluding stripe or not, and whether there was a figure at the location of the RF or not. We determined the average firing rate for each condition and calculated a permanence index PERMI= (OccludedFigure – OccludedNothing) / (VisibleFigure – VisibleNothing). Preliminary results suggest that V4 contains a small proportion of neurons (8/86) with high permanence (PERMI >0.5), whereas no such neurons were found in V2 (0/43). The distribution of recording locations suggests spatial clustering of high permanence neurons within V4. Thus, V4 might be involved in providing object permanence.

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26.4073 **TMS of the frontal eye fields reveals load- and cue-related modulations of cortical excitability and effective connectivity** Amanda van Lamsweerde[1](amanda.vanlamsweerde@ndsu.edu), Andrea Bocincova[1], Andrew Heinz[1], Jeffrey Johnson[1]; [1]North Dakota State University

In a recent study, Reinhart et al. (2012) reported that the amplitude of local field potentials recorded in the macaque FEF during a delayed-saccade working memory task predicted the amplitude of contralateral delay activity (CDA) measured over posterior sensors. This finding suggests that the FEF may contribute to the maintenance of information in WM through feedback inputs to posterior brain regions. In this study, we sought causal evidence for this possibility by using TMS to stimulate the FEF and EEG to measure the strength of the resulting response and its spatial spread to distal cortical areas during WM maintenance. Specifically, subjects completed a cued recall test in which they remembered either two or four colors presented in either the right or left visual hemifield, indicated by a cue at the beginning of each trial. Partway through the WM delay, single pulse TMS was delivered to the right FEF. The resulting TMS-evoked response (TER) was then source-localized and two synthetic measures--significant current density (SCD) and significant current scattering (SCS)--were derived to assess condition-specific changes in cortical excitability and effective connectivity, respectively. Preliminary results (n=6) revealed load- and cue-specific increases in both measures: both SCD and SCS increased when four versus two items were maintained, but this effect was restricted to the condition in which stimuli were encoded from the contralateral visual hemifield. Follow-up analyses examining whether these differences were specific to particular brain regions hypothesized to play a role in WM maintenance revealed that changes in SCD and SCS were most pronounced in the stimulated region, with smaller modulations observed across a range of areas, including bilateral primary and extrastriate visual cortex, among others. Additional planned analyses include an assessment of the relationship between the TER, the amplitude of CDA, and behavioral measures of WM capacity and precision.

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Visual Memory: Cognitive disorders, individual differences

Saturday, May 20, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4074 **Individual differences reveal independent mechanisms for working memory and perceptual serial dependence** Kathy Zhang[1](kathy.zhang@berkeley.edu), David Whitney[1, 2]; [1]Department of Psychology, University of California - Berkeley, [2]Helen Wills Neuroscience Institute, University of California - Berkeley

Objects in the world appear to have stable identities, sometimes more stable than they actually are. This is thought to be facilitated by perceptual serial dependence, and has been reported for orientation, faces, attractiveness, position, among various other visual object domains. The mechanism for serial dependence remains unclear: it has been argued that serial dependence may occur at the level of perception, at the level of decisions, or that serial dependence, being an influence of the past on the perception of the present, may simply be a byproduct of working memory. Here we tested individual differences in perceptual serial dependence for orientation and faces in addition to measures of working memory capacity to try to determine whether serial dependence is indeed correlated with memory. There were substantial individual differences in perceptual serial dependence, but the correlation between orientation and face serial dependence across subjects was approximately zero and non-significant. This indicates that there is some degree of independence and likely separable processes that contribute to serial dependence in the perception of faces and orientation, while also providing evidence against the possibility that serial dependence is a stimulus invariant 'decision' bias. We then compared serial dependence in face and orientation perception to measures of working memory capacity, including an operation span task and a change detection task. While the estimates of working memory capacity were stable across sessions within subjects, each of these measures of working memory was only weakly and non-significantly correlated with perceptual serial dependence of either faces or orientation. These results build on previous ones (Zhang et al, 2015) suggesting that serial dependence operates independently from traditional measures of working memory. They further raise the possibility that serial dependence operates at multiple levels of visual processing.

26.4075 **Time is needed for memory to be biased toward an ensemble average** Byung-Il Oh[1](bioh.inbox@gmail.com), Min-Suk Kang[1,2]; [1]Department of Psychology, Sungkyunkwan University, [2]Center for Neuroscience Imaging Research, Institute for Basic Science

It has been shown that memory of an individual item is biased toward an ensemble average (Brady & Alvarez, 2011; Lew & Vul, 2015). Here we investigated how this bias changes over time by using an orientation estimation task. Participants were presented with 20 oriented white bars for 200 ms on a gray background. In each trial, the stimuli had five orientations that differed by 0, −15, +15, −30, and +30 degrees from a randomly selected orientation, and each orientation was uniformly sampled four times. These 20 stimuli were then randomly presented within an imaginary 4 × 5 grid.

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The participants had to remember those bars and recall the orientation of a target, which was cued with a circular contour. This cue was displayed at one of three different times. In one condition, the stimuli and the cue were simultaneously presented; in other two conditions, the cue was presented 500 ms or 1000 ms after the stimuli onset. Estimation phase started 1500 ms after the stimuli onset such that a randomly oriented probe appeared within the circular cue, and the participants reported the remembered orientation of the target by adjusting the probe orientation. Importantly, the target orientation was either the mean orientation of the 20 stimuli or ±15 degrees from the mean. When the cue was simultaneously presented with the stimuli, the remembered orientation of the target was similar to its physical orientation. However, when the cue was presented 500 ms or 1000 ms after the stimuli onset, the remembered orientation was biased toward the mean orientation of the 20 stimuli. These results suggest that the memory representation is gradually biased toward an ensemble average over time.

Acknowledgement: NRF 2016R1D1A1B03930292

26.4077 **Dissociable Effects of Depressed Mood, Schizotypal Personality Disorder, and Age on the Number and Quality of Visual Working Memory Representations** Weiwei Zhang[1](weiwei.zhang@ucr.edu), Weizhen Xie[1], Marcus Cappiello[1]; [1]Dept. of Psychology, UC Riverside

Limited storage in Visual Working memory (VWM) sets a major constraint on a variety of cognitive and affective processes. Additional reduction of this central bottleneck has been associated with declines in various health related factors such as depressed mood, Schizotypal Personality Disorder (SPD), and age. The present study examined the disruptive effects of these factors on quantitative (i.e., the number of retained representations) and qualitative (i.e., precision) aspects of VWM representations. In two studies, participants completed a short-term color recall task along with questionnaires on mental health including depressed mood, SPD, and demographic information. Study 1 showed that depressed mood was associated with reduced VWM storage capacity, whereas SPD was associated with reduced mnemonic precision (assessed as the inverse of recall variability after randomness in recall was factored out). These patterns were absent in sensory memory, indicating the VWM effects were post-perceptual. Study 2 replicated the reduction in VWM storage capacity by depressed mood and further demonstrated that chronological age negatively correlated with VWM precision. The latter effect remained significant after statistically controlling the contribution of poor sleep quality that was associated with age. These results demonstrate that depression, SPD, and age can have dissociable effects of on VWM representations, in line with the growing literature suggesting that the two aspects of VWM representations can be disassociated using different experimental manipulations and supported by non-overlapping neural mechanisms. Together, these findings support that the quantity of retained VWM representations can be independent of their quality.

26.4078 **Impact of Impaired Spontaneous Grouping on Estimates of Visual Working Memory Capacity in Schizophrenia** Molly Erickson[1](me401@ubhc.rutgers.edu), Brian Keane[1], Dillon Smith[1], Steven Silverstein[1]; [1]Division of Schizophrenia Research, Department of Psychiatry, Rutgers University

Schizophrenia is a mental illness that is associated with working memory (WM) deficits; however, a mechanistic account for these deficits has not yet been identified. Recent evidence suggests that electrophysiological abnormalities during early encoding/consolidation processes may constrain WM capacity in PSZ (Erickson et al., 2016). One hypothesis that dovetails with these observations is that PSZ do not use spontaneous configural grouping strategies to encode and consolidate items in storage the same way that healthy control subjects (HCS) do. The present study was conducted to test this hypothesis. Two HCS and one PSZ have completed the task to date, with an expanded sample size anticipated by May 2017. Participants were exposed to three variants on a change-detection task: (1) a pro-grouping task variant wherein to-be-remembered items (four sectored circles) create an illusory contour defined polygon; (2) an anti-grouping task variant wherein to-be-remembered items are rotated and surrounded by surrounding circles to inhibit illusory contour formation; and (3) a neutral task variant, wherein to-be-remembered items are rotated, but not surrounded by circles that inhibit illusory contour formation. Consistent with our hypothesis, preliminary results suggest that HCS have reduced accuracy in the anti-grouping condition compared to the neutral and pro-grouping conditions. By contrast, PSZ accuracy appears to be improved in the pro-grouping condition compared to either the anti-grouping or neutral task variants. Taken together, these observations suggest that (1) HCS can flexibly use grouping strategies to encode items regardless of whether grouping cues are weak (neutral condition) or strong (pro-grouping condition) to improve WM storage; and (2) poor WM task performance in PSZ may be due in part to decreased use of spontaneous grouping strategies to encode items. This conclusion is supported by evidence that PSZ exhibit improved WM task performance when grouping cues are made more explicit.

26.4079 **Evidence of limited cross-category visual statistical learning in amnesia** Marian Berryhill[1](mberryhill@unr.edu), Adelle Cerreta[1], Timothy Vickery[2]; [1]Department of Psychology, Program in Cognitive and Brain Sciences, University of Nevada, [2]Department of Psychological and Brain Sciences, University of Delaware

The neural correlates of visual statistical learning (VSL) remain debated, but neuroimaging and neuropsychological findings support the emerging view that MTL involvement is needed for this form of implicit learning. We extended new findings showing that performance on classic triplet VSL tasks is interrupted in amnesic patients. We sought to test whether some forms of VSL may persist without intact MTL, by combining stimuli within and between broad categories (faces and scenes) in an otherwise typical VSL paradigm. In Experiment 1, the familiarization task required participants to monitor sequentially presented faces (male/female) and scenes (indoor/outdoor), and to report image flickers. 16 AB pairs were repeated, such that A always predicted B. The nature of these pairs was the key manipulation. To examine how categorical boundaries impact VSL these pairs were consistent (male->male; indoor->indoor), inconsistent (male->female; indoor->outdoor) or cross-category (male->outdoor; indoor->female). During a surprise 2AFC recognition phase, the task was to pick the more familiar pairing versus a foil. Here, the amnesic participant showed chance performance, suggesting no VSL and a reliance of this form of VSL on MTL structures. In Experiment 2, the familiarization task was modified to require a stimulus categorization judgment. During the recognition stage, the patient demonstrated significantly above chance performance for a subset of AB pairs. Surprisingly, her recognition was better for the pairs that crossed category boundaries, regardless of whether the same (male ->outdoor) or a different (male->indoor) motor response was required. She showed this same pattern across two testing sessions separated by more than a week. These data provide additional context to our understanding of the relationship between VSL and the MTL. We found evidence of limited VSL despite profound MTL damage, suggesting that the neural underpinnings of VSL may be more varied and contingent on task demands than previously thought.

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26.4080 **Distortions of spatial memory: Social attention, but not social interaction effects** Tim Vestner[1](tv551@york.ac.uk), Steven Tipper[1], Tom Hartley[1], Shirley-Ann Rueschemeyer[1]; [1]Department of Psychology, University of York

Recent studies have demonstrated the malleability of distance perception in affective/social situations, claiming that distance perception is inherently tied to social experience. Importantly, only an egocentric perspective, involving distances between the observer and a target stimulus, was studied. The present series of experiments investigated whether similar distortions of space also hold true for allocentric conditions. Using a variety of displays presenting individuals in different spatial configurations and various relationships to each other, it was tested whether an observer recalled the distance between individuals as smaller or larger depending on their relationship and level of engagement. Distance-altering effects resulting from the attention-direction of the individuals were found. However, thus far there is no evidence for the influence of the social relationships of the agents on the recall of their distance to each other. These results confirm previous research on attention cueing but are not in agreement with theories proposing social top-down effects on spatial memory.

 See page 3 for Abstract Numbering System

26.4081 **Degradation of object-specific knowledge from atrophy of perirhinal cortex** Amy Price[1](amyroseprice@gmail.com), Amy Halpin[2], Michael Bonner[3], Murray Grossman[2]; [1]Princeton Neuroscience Institute, Princeton University, [2]Department of Neurology, University of Pennsylvania, [3]Department of Psychology, University of Pennsylvania

Over a lifetime of experience, we store information about the objects in our environment and their defining features. One important statistical property for visual objects is the co-occurrence of constituent features. For example, the round shape of an apple co-occurs frequently with the color red, but not blue. Recent fMRI work has shown that a sub-region of the anterior temporal lobe, perirhinal cortex, encodes object-specific information, while lower-level perceptual features are encoded in posterior regions. Here we tested whether perirhinal cortex plays a causal role in object-specific representations by coding object-feature co-occurrence statistics. We examined patients with neurodegenerative disease that, as a group, had atrophy spanning portions of temporal, parietal and frontal cortex. We used a behavioral version of representational similarity analysis to characterize the semantic and perceptual representations of objects in the patients. Through a series of behavioral assessments, we constructed dissimilarity matrices reflecting the patients understanding of feature co-occurrence statistics for each object category, the perceptual similarities for color, and perceptual similarities for simple shapes. We then examined the degree to which the patients' behavioral dissimilarity matrices correlated with those of a control group, which provided a continuous measure of behavioral impairment for each task in every patient. We tested for neural regions that underlie these representations by examining correlations with neuroimaging measures of cortical atrophy. Consistent with our predictions, we found that the degree of atrophy of perirhinal cortex was strongly correlated with the degree to which patients were impaired on knowledge of object-feature statistics but not with their perceptual assessments of color and shape information, which appeared to rely on more posterior regions of the ventral stream. These results situate perirhinal cortex at the interface of perception and semantic memory, and demonstrate its critical role in coding the statistical regularities that define an object category.

Multisensory: Touch and balance

Saturday, May 20, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4082 **Measuring end-to-end latency of a virtual reality system objectively and psychophysically** Andrew Glennerster[1](a.glennerster@reading.ac.uk), Stuart Gilson[2]; [1]School of Psychology and Clinical Language Sciences, University of Reading, UK, [2]Department of Optometry and Visual Science, University College of Southeast Norway

Reduction of end-to-end latency ('motion-to-photons') is critical for convincing, high-fidelity virtual reality and for scientific uses of VR that mimic real world interactions as closely as possible. We measured the end-to-end latency of a real-time infra-red camera-based tracking system (Vicon), with rendering on a standard graphics PC and using a head mounted display (nVis SX111 HMD). A 100Hz camera captured both a tracked 'wand' and the rendered object (a sphere) on the display screen as the wand was moved from side to side. Cross-correlation of the centroid positions of the tracked wand and rendered sphere allowed us to calculate the end-to-end latency of the system for different displays. With our HMD (LCD display), this was about 40ms (± 2ms) whereas for a CRT it was 30ms. Because our display was refreshed at 60Hz and rendering time was less than 16.6ms, we could wait for the latest possible Vicon tracker coordinate (available at 250Hz) before rendering the next frame and swapping buffers. This reduced latency by 9ms (to 31ms). In a psychophysical experiment, we showed that a reduction in latency of this magnitude was easily detectable. Three observers waved a wand, rendered as a multi-faceted ball and, in a forced-choice paradigm, identified whether the latency between hand movement and rendered stimulus movement was 'high' or 'low' (50% of trials were of each type; 4 practice trials including both types preceded each run). We varied the latency difference by a combination of (i) adding artificial latency to one stimulus and (ii) minimizing the latency of the shorter latency stimulus. Plotting d' against log latency difference and fitting a straight line showed that the threshold difference (d' = 1) was less than 4ms for all participants. This corresponds to a remarkably low Weber fraction of about 10%.

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26.4083 **Multimodal Contributions to Subjective Visual Vertical** Chéla Willey[1](cwilley@ucla.edu), Zili Liu[1]; [1]Department of Psychology, College of Life Sciences, University of California, Los Angeles (UCLA)

We investigated the perception of subjective visual vertical (SVV) as a result of visuo-vestibuo-proprioceptive integration. Estimates of vertical are typically made by rotating a rod in space to a vertical position while standing upright. The visual context in which the rod is presented can influence SVV estimates as follows. In the rod and frame task, SVV estimates are biased towards the orientation of a surrounding contextual frame. However, SVV may also be influenced by vestibular and proprioceptive input indicating the direction of gravity. We sought to measure the effect of these modalities in SVV estimates by reducing their contribution in four conditions. Participants performed the rod and frame task while standing upright and while lying down using a virtual reality headset. This allowed us to eliminate contributing information due to vestibular gravitational cues available in the upright position. The use of virtual reality also allowed for the immersed visual illusion of the upright position in the supine condition. Further, we manipulated proprioceptive input by applying vibration to the participants' back in the supine position, the feet in the upright position and to the neck in both positions during half of the trials in each body orientation condition. During repeated trials, participants judged the orientation (clockwise or counterclockwise) of the rod located at the center of a neutral or rotated 3D frame. We found that there was an increase in bias towards the orientation of the frame and a decrease in sensitivity in SVV estimates in the supine conditions as compared to upright conditions, suggesting an effect of vestibular information. However, we found limited support that proprioceptive information (without vibration) influenced SVV estimates in the current study. Our results suggest that SVV estimates are more heavily influenced by visual cues when there is a lack of available vestibular cues.

26.4084 **Effect of Vibrotactile Feedback through the Floor on Social Presence in an Immersive Virtual Environment** Myungho Lee[1](myungho@knights.ucf.edu), Gerd Bruder[1], Greg Welch[1]; [1]University of Central Florida

Despite the multisensory nature of human perception, applications involving virtual humans are typically limited to visual stimulation and speech. We performed an experiment investigating the effects of combined visual, auditory and/or vibrotactile stimuli on a participant's sense of social presence with a virtual human. In an immersive virtual environment achieved via a head-mounted display, the participants were exposed to a virtual human (VH) walking toward them and pacing back and forth, within their social space. Participants were randomly assigned to one of three conditions: participants in the "Sound" condition (N=11) received spatial auditive feedback of the ground impact of the footsteps of the VH; participants in the "Vibration" condition (N=10) received additional vibrotactile feedback from the footsteps of the VH via a haptic platform; while participants in the "Mute" condition (N=11) were not exposed to sound or vibrotactile feedback. We measured presence/social presence via questionnaires. We analyzed the participants' head movement data regarding backing away behaviors when the VH invaded the participant's personal space as well as the view direction toward the face of the VH. Our results show that social presence and the backing away distance in the Vibration condition were significantly higher than in the Sound condition. Presence in the Mute condition was significantly lower than in the other two conditions. The vibrotactile feedback of a VH's footsteps increased the social presence in both subjective self-reports of the sense of social presence and behavioral responses when it was accompanied by sounds, compared to vision and sounds only. We found that participants who experienced both the footstep sounds and vibrations exhibited a greater avoidance behavior to the VH, e.g., avoided looking at the VH's face directly and moved their head backward more when the VH invaded their personal space.

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Saturday PM

26.4085 Spatiotemporal dynamics of braille letter perception in blind readers Santani Teng[1](santani@mit.edu), Radoslaw Cichy[3], Dimitrios Pantazis[2], Aude Oliva[1]; [1]CSAIL, Massachusetts Institute of Technology, [2]McGovern Institute for Brain Research, Massachusetts Institute of Technology, [3]Department of Education and Psychology, Free University of Berlin

Traditionally "visual" cortical regions in blind persons are known to activate in response to a wide range of nonvisual tasks, suggesting a functional reorganization in response to blindness. However, the functional correlates of specific regional activations and, more generally, the principles governing the reorganization of cortical processing remain unclear. This is in part because the underlying dynamics of crossmodal plasticity are not well understood. Previously, we measured brain responses to Braille letter stimuli using MEG alone, finding that sensory representations are widely variable and idiosyncratic across subjects. Thus, to elucidate the braille processing stream in blind individuals with high spatial resolution, here we additionally measure fMRI responses in repeated sessions for individual subjects. Early-blind, braille-proficient participants were presented with single-letter stimuli to the left index finger in random order, responding to occasional deviants. Univariate contrasts yielded reliable BOLD activation in right somatosensory and bilateral occipital and parietal cortices. Further, we use MVPA to generate similarity matrices between letter identities from MEG and fMRI data. We then relate these results with representational similarity analysis, leveraging the spatial resolution of fMRI and the temporal resolution of MEG in a spatiotemporal fusion analysis: Significant correlations between MEG and fMRI representations index the propagation of braille information between its arrival in somatosensory cortex and its subsequent evolution along the processing stream. We interpret results in the context of competing proposals of processing hierarchies, e.g. whether a visually deprived cortex reverses the typical visual hierarchy or largely co-opts it using tactile input.

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26.4086 Estimation of gloss and shape from vision and touch. Wendy Adams[1](w.adams@soton.ac.uk), Gizem Küçükoğlu[2], Michael Landy[2]; [1]Department of Psychology, University of Southampton, [2]Department of Psychology, New York University

Image cues to gloss are affected by both gloss and shape. For this reason, an optimal observer would jointly estimate gloss and shape. Consistent with this, we have shown that underestimation of depth is associated with overestimation of gloss, and vice versa. If observers jointly estimate shape and gloss, using all available information, then shape cues from another modality, such as haptics (touch) should modulate perceived gloss. Observers viewed and touched visual-haptic stimuli that independently varied in depth and gloss. The shape information provided by touch was either consistent with vision, or differed by ±15%. On each trial, observers reported both perceived depth and perceived gloss, with reference to two sets of physical stimuli: one varied in gloss (painted ping pong balls with varying mixtures of matte and glossy varnish), the other in depth (3-D printed arrays of random-depth ellipses similar to the visually and haptically rendered stimuli). As expected, perceived depth increased as a function of both visually and haptically defined depth; observers integrated the depth information provided by the two modalities. In addition, and in line with previous findings, perceived gloss was affected by both visually rendered gloss and visually rendered depth: perceived gloss increased with visually-defined depth. However, the haptic depth perturbations had little effect on perceived gloss. Subtle changes in quantitative depth, signalled by a non-visual modality do not appear to modulate the perceived glossiness of a surface.

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26.4087 The role of proprioception in visuo-haptic size perception Robert Volcic[1](robert.volcic@nyu.edu), Nadeen Alalami[1]; [1]Department of Psychology, New York University Abu Dhabi

Constancy in visual size perception is generally incomplete: the perceived size is affected by changes in fixation distance. Whether haptic and visuo-haptic size perception is subject to the same lack of constancy is, however, as yet unknown. In principle, haptic size perception should not be affected by changes in hand position and should thus be unbiased. But, if so, which sense dominates visuo-haptic size perception? Here we show that visuo-haptic size perception is more than the simple combination of visually and haptically sensed dimensions. Specifically, in Experiment 1, we asked participants to judge the size of two objects placed at different egocentric distances in visual, haptic and visuo-haptic conditions. The point of subjective equality and the discrimination threshold, determined with an adaptive staircase procedure, were taken as a measure of size constancy and precision, respectively. We found a lack of size constancy in both visual and haptic conditions but, surprisingly, not in the visuo-haptic condition. Precision was lowest in the haptic condition with no advantage of the visuo-haptic condition over the visual condition. In Experiment 2, we tested two possibilities that may explain these results. The first was that participants might have estimated the size of objects by comparing them to their own visible hand. The second was that they might have scaled retinal size by the haptically sensed distance. To contrast these two possibilities, we manipulated whether participants could see their hand while grasping objects in the visuo-haptic condition. We found that participants' size constancy and precision were not impacted by the availability of hand vision. In sum, our findings show that imperfect size constancy is found also in haptics, and suggest that visuo-haptic size perception comprises the proprioceptive information about the hand position which promotes visual processing of object's properties.

26.4088 Hand as a Deformable Sensor: Toward a Quantitative Framework for Characterizing 4D Dynamics of the Hand during Visual-Haptic Cross-Modal Perception Jay Hegdé[1,2,3](jay@hegde.us); [1]Brain and Behavior Discovery Institute, James and Jean Culver Vision Discovery Institute, Department of Ophthalmology, Medical College of Georgia, Augusta University, Augusta, GA

During haptic exploration of objects, the hand undergoes complex and dynamic shape changes, or deformations. Deformations in the sensor inevitably introduce distortions in the sensory information. Therefore, in order to perceive the object properly, the brain must, in computational terms, 'discount' hand deformations during visual-haptic cross-modal perception. This process is poorly understood, in no small measure because of a lack of a quantitative understanding of the deformations of hand during haptic exploration. To help overcome this barrier, we used a 3D scanner to measure the 3D shape of both hands at rest and during haptic exploration in 7 adult human subjects (5 females) at an average spatial resolution of 0.62 mm ± 0.54 [SD]. As the requisite first step in developing a 4D framework for hand representations, we constructed, for the first time, a standard coordinate system (or map) for hands, akin to those that already exist for brains. The standard hand map derived by the coregistering the 14 individual hands using different available algorithms yielded comparable results (average pairwise cophenetic correlation = 0.43, df > 3x104, p < 10-5). Reassuringly, distortions in the map were smallest at the tip of each finger (mean error, 0.71 mm ± 0.49) where haptic sensitivity is known to be the highest. Distortions were largest over the opisthenar and the purlicue (4.57 mm ± 2.14), which are relatively unimportant in haptic sensing. To help validate the map, we determined the extent to which locations of three of the most sensitive locations of the hand (fingertips of forefinger, thumb, and middle finger) from individual hands matched the corresponding locations in the standard hand. We found that these errors were relatively small (0.52 mm ± 0.34). Together, our results demonstrate the feasibility of representing hand dynamics during haptic explorations within a standard coordinate system.

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26.4089 Eye and hand dissociation in depth and direction: behavioral encoding of reach Annalisa Bosco[1](annalisa.bosco2@unibo.it), Valentina Piserchia[1], Patrizia Fattori[1]; [1]Department of Pharmacy and Biotechnology, University of Bologna

The encoding of reaching towards targets in 3-dimensional space has been studied at behavioral level. However, the contribution of coordinate systems to movement control for dissociated reaches where eye and target positions varied both in direction and depth is not fully understood. Twelve healthy participants were tested in a memory guided task where reaching targets were presented at different depths and directions in foveal and peripheral viewing conditions. The peripheral and foveal viewing conditions consisted in three eye/hand configurations: in the constant-gaze configuration, the eyes fixated a central fixation target and the hand reached one of the peripheral reaching targets, in the constant reach configuration, the eyes fixated one of the peripheral targets and the hand reached always the central target, and in the foveal reach configuration, the fixation and reaching targets were coincident. A novel approach for behavioral data was used to define the prevalent coordinate system used by each subject and it consisted in the application of combined gradient and vector analysis. The results showed reach error patterns that are based on both eye-centered and space-centered representation: in depth more deviated towards a space-centered representation and in direction perfectly balanced between eye-centered and space-centered. We correlated the trajectory variability in eye-centered and space-centered coordinates and we found that, in direction, the variability was described by a combination of linear and non linear model and, in depth, by a significant linear model. Present data indicate that the different weights of coordinate systems found in depth and direction are correlated with the variability distribution across eye/target configurations. In particular, the non linear distribution of movement variability in direction can be related to a mixed encoding and the linear distribution in depth with a more defined spatiotopic encoding.

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26.4090 **Causal inference in the updating and weighting of allocentric and egocentric information for spatial constancy during whole-body motion** Florian Perdreau[1](f.perdreau@donders.ru.nl), Mathieu Koppen[1], Pieter Medendorp[1]; [1]Radboud University, Donders Institute for Brain, Cognition & Behaviour, Nijmegen, Netherlands

It has been reported that the brain combines egocentric and allocentric information to update object positions after an intervening movement. Studies typically use discrete updating tasks (i.e., comparing pre- to post-movement target representations). Such approaches, however, cannot reveal how the brain would weigh the information in these reference frames during the intervening motion. A reasonable assumption is that objects with stable position over time would be more likely to be considered as a reliable allocentric landmark. But inferring whether an object is stable in space while the observer is moving involves attributing perceived changes in location to either the object's or the observer's displacement. Here, we tested this causal inference hypothesis by designing a continuous whole-body motion updating task. At the beginning of a trial, a target was presented for 500 ms, within a large visual frame. As soon as the target disappeared, participants were asked to move a cursor to this location by controlling a linear-guide mounted on the vestibular sled on which they were seated. Participants were translated sideways as soon as their reaching movement started, and they had to maintain the cursor on the remembered target location in space while being moved. During the sled motion, the frame would move with a velocity proportional to that of the sled (gain ranging from -0.7 to 0.7). Participants' responses showed a systematic bias in the direction of the frame displacement, one that increased with the difference between the frame and the sled velocity for small differences, but was decreasing for large differences. This bias pattern provides evidence for humans exploiting a dynamic Bayesian inference process with two causal structures to mediate the dynamic integration of allocentric and egocentric information in spatial updating.

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26.4091 **Suppressive mechanism in motion perception correlates with postural control ability** Liana Saftari[1](lianasaftari@unist.ac.kr), Shuping Xiong[2], Oh-Sang Kwon[1]; [1]Department of Human Factors Engineering, UNIST, Ulsan, South Korea, [2]Department of Industrial and Systems Engineering, KAIST, Daejeon, South Korea

Motivation: To properly control postural balance, good coordination between visual, vestibular and muscle control system must be maintained. It has been documented that deteriorated visual abilities such as visual acuity, contrast sensitivity and depth perception are related to the deficits in postural control. However, little attention has been paid to the relation between motion detection sensitivity and postural control, which is an important gap in literature because motion signal is crucial in maintaining balance. Methods: Twenty older (67-78) and twenty young adults (19-24) underwent series of tasks measuring visual and postural control abilities. Visual tasks include visual acuity, contrast sensitivity, depth perception and motion sensitivity tasks. Motion sensitivity was determined by measuring duration thresholds in two sizes and two contrasts conditions. Postural control tasks include maintaining upright stance in different combination of visual aid and floor conditions, and shifting the center of mass to certain location without stepping out from initial position. Results: We replicated existing findings that contrast sensitivity and visual acuity are related to the ability of shifting center of mass accurately ($P< 0.01$, $r=0.523$ and $P< 0.01$, $r=0.526$ respectively). More importantly, we found that motion sensitivities to different size of stimulus are related to different abilities of balance control. Sensitivity to large motion stimulus is negatively correlated with the ability of maintaining upright stance ($P< 0.001$, $r=-0.540$), and sensitivity to small motion stimulus is positively correlated with the ability of shifting center of mass accurately ($P< 0.001$, $r=0.670$). Discussion: The improvement of perceptual sensitivity to a large-high contrast motion in older adults indicates that deteriorated ability of suppressing irrelevant motion signals. Our current finding that the size of motion stimulus affects the correlation between motion perception and balancing differently suggests that suppression of irrelevant peripheral motion signal might have critical role in controlling balance.

Acknowledgement: This research was supported by the National Research Foundation of Korea (NRF-2015R1D1A1A01060520)

Saturday PM

26.4092 **Interaction Effect of Frequency, Velocity and Amplitude on Perceived Vection Magnitude for Yaw Visual Oscillation** Xiao FU[1](fuxiaojin32@gmail.com), Yue WEI[2], Daniel CHEN[1], Richard SO[1,2]; [1]Department of Industrial Engineering and Logistics Management, The Hong Kong University of Science and Technology, Hong Kong, PRC, [2]Division of Bio-medical Engineering, The Hong Kong University of Science and Technology, Hong Kong, PRC

The phenomenon of vection (also referred to as illusive sensation of self-motion) is commonly perceived by stationary observers when watching coherently moving visual stimuli. For oscillatory visual stimuli, relation of the oscillation frequency (f), root-mean-squared (RMS) velocity (v), and amplitude (A), is $v=\sqrt{2}\pi fA$. Previous studies in our lab showed that, when stimuli oscillating along the fore-and-aft axis, the influences of frequency on perceived vection depended on amplitude and RMS velocity, which indicated that these three factors had interactive influences on perceived vection. This study examined the effects of these three factors when viewers were watching visual scenes oscillating along the yaw axis. The experiment consisted of 4 repeated sessions in separate days adopting a within subjects design. Subjects were exposed to a virtual optokinetic drum, with alternated black-and-white stripes oscillating sinusoidally. Preliminary data from the first 8 subjects (gender balanced) showed that when visual oscillations were of the same frequency, perceived vection magnitude became stronger first and then turned weaker as the velocity (or amplitude) increased (see supplemental materials). Analyses of the main effects of amplitude indicated that the larger the amplitude, the stronger the perceived vection. However, when the velocity became very large, the increases in perceived vection due to larger amplitude could not compensate the reduction of vection due to the increases in velocity in order to maintain the same frequency. In conclusion, exposure to visual oscillations along the yaw axis of the same frequency but different amplitudes and velocities could generate different vection magnitudes due to the interacting effects of velocity and amplitude. Findings suggested that frequency alone should not be regarded as a sufficient predictor for perceived vection magnitude.

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Spatial Vision: Crowding and masking

Saturday, May 20, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4093 **Crowding asymmetries in a neural model of image segmentation** Alban Bornet[1](alban.bornet@epfl.ch), Adrien Doerig[1], Michael Herzog[1], Gregory Francis[2]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, [2]Department of Psychological Sciences, Purdue University, USA

In crowding, perception of a target deteriorates when neighbored by flankers. Contrary to predictions of classic pooling models, crowding is strong only when the target groups with the flankers. We recently showed that a version of the neural LAMINART model could explain many grouping effects in crowding. In the model, top-down segmentation signals promote separate neural representations of separate groups in a scene. The model is implemented as spiking neurons in the NEST simulator, consists of hundreds of thousands of neurons and several million connections, and represents early stages of vision (V1, V2 and V4). Here, we present new simulations that hypothesize that the placement of the top-down signal is less precise for more peripheral locations. The overall strength of crowding for flankers depends on whether the top-down signal can generate distinct segmentations of the target and a flanker. A flanking set of 8 long lines spans a large surface that the top-down signal will easily catch and segment from the target vernier, so such segmentations will be very common regardless of distance from fixation. In contrast, a flanking square can, in principle, be segmented from the target, but such segmentations will be less common with larger distances from fixation. These properties produce the predicted crowding asymmetry: when the target is in the right-side visual field, crowding is stronger with long-sized lines flanking the target on the left (closer to fixation) and a square flanking the target on the right (farther from fixation) than when the flanker locations are switched. In an empirical study, 6 observers discriminated a target vernier with the stimuli used in the simulations. Consistent with the model predictions, crowding was stronger with an array of aligned flankers to the left and a square to the right compared to the other way around.

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26.4094 **Perceptual Grouping and Segmentation: Uncrowding**

Gregory Francis[1](gfrancis@purdue.edu), Alban Bornet[2], Adrien Doerig[2], Michael Herzog[2]; [1]Psychological Sciences, Purdue University, [2]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne

In visual crowding a target stimulus can be difficult to identify or discriminate when it is surrounded by additional flanking elements. Numerous empirical studies have demonstrated that the strength of crowding depends on the apparent grouping relationship between the target and flanking elements. Last year (Francis, Manassi & Herzog, 2016), we described a neural network model of visual perception that explained a wide variety of crowding effects as the result of neural grouping and segmentation mechanisms. We now present new model simulations of an uncrowding effect, where a single stimulus around a target causes strong crowding but additional flanking stimuli produce weaker crowding effects. Manassi, Lonchampt, Clarke & Herzog (JOV, 2016) investigated more than a dozen such uncrowding examples; and our new simulations demonstrate that the neural network model accounts for many of these new uncrowding examples because adding flanking elements leads to a larger perceptual group of flankers that is distinct from the target. This larger group is more easily segmented by top-down signals that produce distinct representations of the target and the group of flankers. These distinct representations avoid crowding effects because the segmentation process effectively isolates the target. Consistent with the new empirical data, the model demonstrates uncrowding for flankers made of squares, circles, hexagons, octagons, stars, and irregular shapes, as long as they form perceptual groups. The model fails to match empirical findings for some situations where grouping effects seem to be very sensitive to contextual details; a failure that is not too surprising since the model grouping mechanisms do not perfectly match human behavior. Overall, the model is able to account for many new cases of uncrowding; and the cases where the model is unsatisfactory suggest ways to improve the model to better understand crowding effects, perceptual grouping, and visual segmentation.

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26.4095 **On the heterogeneity of visual crowding**

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Our ability to identify a visual object in clutter is far worse than predicted by the eyes' optics and nerve fiber density. Although the ubiquity of such visual impairment, referred to as crowding, is generally well accepted, the appearance of crowded stimuli is debated due in part to the fact that the patterns of perceptual errors made under crowded conditions depend somewhat on the specific task. For example, using stimuli that do not easily combine to form a unique symbol (e.g. letters or objects), observers typically confuse the source of objects and report either the target or a distractor. Alternatively, when continuous features are used (e.g. orientated gratings or line positions), observers often report a feature matching the average of target and distractor features. To help reconcile these empirical differences, we developed a method of adjustment that allows detailed analysis of multiple error categories occurring within the one task. We presented a Landolt C target oriented randomly at 10° eccentricity in the right peripheral visual field in one of several distractor conditions. To report the target orientation, an observer adjusted an identical foveal target. We converted each perceptual report into angular distances from the target orientation and from the orientations of the various distractor elements. We applied new analyses and modelling to these data to quantify whether perceptual reports show evidence of positional uncertainty, source confusion, and featural averaging on a trial-by-trial basis. Our results show that observers reported a distractor orientation instead of the target in more than 50% of trials in some conditions. Our data also reveal a heterogeneous distribution of perceptual reports that depends on target-distractor distance. We conclude that aggregate performance in visual crowding cannot be neatly labelled, and the appearance of a crowded display is probabilistic.

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26.4096 **Un-crowding affects cortical activation in V1 differently from LOC**

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In crowding, neighboring elements impede the perception of a target. Surprisingly, increasing the number of neighboring elements can decrease crowding, i.e., lead to uncrowding (Manassi, 2015). Here, we used fMRI to investigate the cortical locus of (un)crowding. The experiment consisted of seven conditions: (1) target only (eight circular target gratings surrounding a central fixation dot, tilted either clockwise (CW) or counterclockwise (CCW)), (2) 2-flanker (each of the 8 targets was flanked by an inside and outside vertically-oriented grating), (3) annulus-flanker (inside and outside flankers connected into annuli), (4) 4-flanker (one inside and three outside gratings), and (5-7) control conditions corresponding to conditions (2-4) with targets removed. Participants were asked either to indicate whether target gratings were tilted CW or CCW by pushing one of two buttons or to push a button randomly if targets were not present. Target discrimination was highest in the target only condition, followed by the annulus-flanker, 4-flanker and 2-flanker conditions, respectively. As crowding is known to attenuate the BOLD response, we predicted that the percent signal change (PSC) closely reflects the behavioral results (successive decrease in target identification from annulus-flanker to 4-flanker to 2-flanker) in brain areas underlying the crowding effect. The PSC was calculated for each subject, each region of interest (target-activated areas in V1–V4 and LOC) and each of the conditions of interest. In fMRI, crowding and uncrowding effects were present throughout areas V1–V4 and LOC, as indicated by comparisons of PSCs in the target only versus 2-flanker and 4-flanker conditions. However, the more fine-grained differences between the 2-flanker condition and the 4-flanker and annulus-flanker conditions were only present in V1, V4 and LOC. The expected successive decrease in PSC from annulus-flanker to 4-flanker to 2-flanker was only observed in the LOC, reflecting uncrowding.

26.4097 **Relationships between retinal ganglion cells, Ricco's area and crowding zone**

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Previous studies reported enlargements in the area of complete spatial summation (Ricco's area) for luminance detection in response to loss of Retinal Ganglion Cells (Redmond et al., 2010). While the finding suggests the integrity of RGCs may alter spatial pooling properties, little is known about its impact on the pooling mechanisms of complex object recognition. Here we examine the relationships between RGC layer thickness, Ricco's area and crowding zone. Ten normally-sighted subjects participated in the study. For Ricco's area, a subject's contrast detection threshold was measured using a luminance-disc with varying diameter. Two-limbed functions were fitted to the data of log detection threshold versus log stimulus area. Ricco's area was defined as the breakpoint of the two-limbed function. For crowding zone, a subject's contrast recognition threshold was measured using a flanked letter with varying center-to-center spacing between the target and flankers. Clipped lines were fitted to the data of log recognition threshold versus spacing. Crowding zone was defined as the minimum spacing that yields no threshold elevation in the fit. Measurements were made at 4 locations (at the eccentricity 8.5°). The RGC plus inner plexiform (RGC+) layer thickness in the central 20° visual-field was measured by Spectral-Domain Optical Coherence Tomography. We found that the RGC+ layer thickness correlated with both Ricco's area ($r=-0.58, p< 0.01$), and crowding zone ($r=-0.31$, $p=0.05$). A significant correlation between Ricco's area and crowding zone was also found ($r=0.58, p< 0.01$). Regression analysis showed a decrease of 1 μm in the RGC+ layer thickness enlarges crowding zone by 0.02° while an increase of 1° in Ricco's area (in diameter) enlarges crowding zone by 4°. Our results demonstrated close relationships between RGCs, Ricco's area and crowding zone even in healthy eyes. Our findings further support the view that changes in RGCs may alter the properties of spatial integration zone.

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26.4098 The effect of overall stimulus configuration on crowding

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Since its inception, the standard framework to study vision has been, implicitly or explicitly, both hierarchical and feedforward. This framework has facilitated the deconstruction of complex mechanisms into smaller, more tractable problems, and has been extremely successful in characterizing the processing of basic visual elements. However, this framework can break down when elements are presented in context, as they are in every-day life. In crowding, peripheral object discrimination is hindered by the presence of nearby elements, as for example a Vernier embedded in a square is more difficult to discriminate than when presented alone. However, adding additional flanking squares can, counter-intuitively, ameliorate this deleterious effect (Manassi et al, 2013, J Vis). This example demonstrates how, in order to understand low-level vision, we must also understand higher-level processing. Here, we take a step toward this integrated approach by characterizing the effect of flanker configuration on crowding in a theory-agnostic manner. Previous studies have examined a small number of experimenter-selected configurations, whereas here we made no assumptions about which configurations should affect crowding. We placed a Vernier embedded in a square at the centre of all possible 3x5 arrays with an equal number of squares and stars (3432 total). Six observers discriminated this Vernier in the presence of each configuration, repeating each until responding incorrectly or achieving six correct responses in its presence. In this way, we were able to quantify the effect of all possible configurations on performance. Among the many interesting patterns in our large data set, we observed a strong positive correlation between the number of clustered square elements and discrimination performance, as well as evidence for an effect of symmetry. More generally, our data suggest that configurations encouraging separate grouping of target and flanker elements ameliorate crowding, using a paradigm in which grouping was not explicitly manipulated.

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26.4099 Are there benefits of Visual Crowding?

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Objects in peripheral vision are less identifiable when flanked by nearby distractors. This loss in performance, known as visual crowding, has traditionally been viewed to result from a bottleneck in visual processing (e.g. Levi, Vision Research, 2008). Here we will present the alternate view that crowding could serve to suppress the representation of repetitive items in peripheral vision so that attentional resources can be directed to non-repetitive, interesting and novel items, potentially as the targets of upcoming saccades. Traditionally, crowding experiments have maximized the degradation of target-object identification by presenting targets and distractors with similar characteristics (Kooi et al., Spatial Vision, 1994) or that group together strongly (Manassi et al., Journal of Vision, 2012). These conditions yield robust target-flanker interactions extending over long distances (Bouma, Nature 1970; Tripathy et al., Journal of Vision, 2014). However, rather than representing a limitation of peripheral visual processing, the strong suppression of repetitive or similar items might be desirable, serving to enhance the individuation and processing of eccentrically viewed novel objects. In agreement with this interpretation, crowding is known to be minimal in foveal vision, is strongest between repetitive or similar objects in peripheral vision and between items that readily group together, and is reduced by target-flanker differences in contrast polarity, color, depth, shape, or complexity. Crowding also is weakened when transients increase the conspicuity of the target relative to the flankers and when the target represents the end-point of a planned saccade. This presentation will evaluate previous studies of crowding to ascertain whether the results can be understood better in terms of an implicit deficit in the processing of nearby visual targets or in terms of a beneficial suppression of repetitive peripheral stimuli so that processing resources can be devoted more fully to unfixated objects that are novel and potentially interesting.

26.4100 Cross-optotype metrics for foveal lateral masking

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A reliable unified metric for the effects of lateral masking on foveal visual acuity remains important and elusive due to the variety of optotypes and spacings used, especially for clinical testing of children. We sought to find a measure of lateral masking that is conserved across clinical optotypes. We asked: 1) Does a target surrounded by pictures or symbols produce similar effects to letters? 2) How do these relate to the effects of bars or a box? 3) Is any masking metric conserved across the different stroke:size ratios of HOTV (5:1), Lea Symbols (7:1), and Kay Pictures (10:1)? For three adults, the method of constant stimuli yielded psychometric functions of performance versus target size for three flanker conditions (box, bars, similar optotypes). Visual acuities and psychometric function slopes were estimated for eight target-flanker separations (0-10 stroke-widths) and for an isolated optotype. A clinical staircase was used separately on 16 adults to estimate acuity for an isolated optotype and the optimal flanker position for each of 3 metrics (stroke-width edge-to-edge; arcmin edge-to-edge; optotype-width centre-to-centre). A repeated measures ANOVA performed on laboratory data revealed that the visual acuity versus flanker separation (in stroke-widths) function was conserved across HOTV, Lea symbols, and Kay pictures. Psychometric function slopes (performance versus target size) were significantly steeper than for isolated targets when flankers were 2 stroke widths away. Lateral masking was estimated from clinical staircases. It was strongest when flankers were similar optotypes. It was conserved across optotypes when using units of either stroke-width or arcmin. When data from both groups were combined, lateral masking was best conserved when expressed as edge-to-edge spacing in units of stroke-width. Lateral masking effects on visual acuity measures are most consistent when surrounding flankers are similar optotypes and units of stroke-width are used to specify separation.

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26.4101 Topological dominance in peripheral vision

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Previous studies have shown that the speed of visual information processing increases with eccentricity. Researches have also demonstrated that the visual system is sensitive to topological changes, such as the appearance and disappearance of holes in a figure. Our results suggest that, compared to foveal vision, the peripheral vision is more engaged in the rapid detection of topological changes. We employed a change detection task with eye movement monitoring. One of the moving figures underwent an abrupt shape change either with a change of hole number ("HC") or without ("nHC"). In 7 experiments, many local features (e.g. luminance, similarity, spatial frequency, perimeter and shape of the contour) were well controlled. The detection performance was quantified as d′. The results showed that the d′ under the "HC" condition was significantly larger in the periphery than it in the fovea, whereas the "nHC" condition manifested significantly larger d′ in fovea than in periphery. The luminance contrast was manipulated to control for the task difficulty. There were 6 experiments consistently showed the advantage of "HC" detection in the periphery. And the consistent finding was also revealed by a random motion paradigm. When the stimulus size was scaled in the periphery according to the cortical magnification theory, the topological advantage cannot be diminished. Moreover, measuring at more eccentricities and even at the eccentricity of 30°, the performance of "HC" retained its sensitivity while "nHC" deteriorated with eccentricity increased. Further, in our fMRI experiment, the response to the "HC" at periphery condition was contrasted with the activation in response to the "nHC" at periphery condition. The result revealed a major activation in the anterior temporal lobe. The observed sensitivity advantage in periphery may support the view that topological definition of objects provides a coherent account for the object perception in the peripheral vision.

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26.4102 Crowding and binding: Not all feature-dimensions behave equally

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Background. Crowding refers to the failure to identify a peripheral item in clutter. The nature of crowding and the stage at which it occurs are still debated. Crowding has been proposed as the consequence of averaging of nearby features (mixture model), and switch between target and distractor objects (swapping model). We use a novel quantitative approach to disambiguate these two hypotheses and assess the stage of processing at which crowding occurs by characterizing errors and the interdependency of different feature-dimensions. Methods. Observers (n=14) estimated the orientation and spatial frequency (SF) of a Gabor (Exp.1) or the orientation and color of a "T" (Exp.2) via two separate reports. The target was presented at 7° eccentricity. In the crowding conditions, two distractors flanked the target, each with unique features. We characterized crowding errors with respect to each distractor along the two feature-dimensions. We compared two probabilistic models –mixture and swap– to characterize the error distributions for each feature-dimension independently and with respect to the other dimension. Results. Under crowded conditions, the swapping model performed significantly better than the mixture model for orientation and color estimation errors, indicating switch between target and distractor. However, the mixture model better characterized SF errors, indicating averaging across target and distractors. Regarding interdependency, whereas color and orientation swapped independently from each other, SF and orientation errors correlated; the probability to swap orientation with a given distractor was independent of the direction of the color error, but higher when SF error was toward that distractor. Conclusion. Crowding leads to the swapping of color and orientation but averaging of orientation and SF. Whereas orientation and color crowding are independent, orientation and SF are interdependent. Our results suggest that crowding operates after orientation is bound with SF but before it is bound with color.

26.4103 The alleviation of crowding effect through perceptual learning

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Our recent study showed that crowding effect can be completely eliminated by perceptual learning (Zhu, Fan, and Fang, JOV 2016). Here, we present data to further characterize this process. Subjects were trained on a crowded orientation discrimination task with a target centered at 10° eccentricity together with two abutting flankers positioned radially. The target and flankers were a circular patch of a sine-wave grating. Before and after training, we measured orientation discrimination thresholds with the crowded and isolated targets. In Experiment 1, the diameter of the target and flankers could be 1.5°, 2°, 2.5° or 3°. We found that the extent of alleviation of the crowding effect by training depended on the center-to-center distance between the target and flankers. The greater the distance, the less crowding effect after training. When the distance was larger than 3°, the crowding effect can be completely eliminated. In Experiment 2, we first replicated our previous finding that there was little transfer of the learning effect between the left and right visual fields. A new finding is that the learning effect to eliminate crowding could completely transfer from the upper to the lower visual filed, but not vice versa. In Experiment 3, we examined whether the learned ability to eliminate the orientation crowding could generalize to eliminate letter crowding. Before and after training, we also measured the contrast thresholds for identifying crowded and isolated target letters, which had the same size as and were placed at the same location as the target grating. We found that the learning effect could completely transfer and eliminate the letter crowding effect. Taken together, these results suggest that, with a relative large target, crowding effect is dominated by some high-level cognitive components, though constrained by visual hemifield properties. The cognitive components can be modified by perceptual training.

26.4104 Invariant tuning of lateral interactions between visual stimuli

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Perception of visual stimuli is modulated by their context. The effect of context can be facilitatory or suppressive in a manner that is highly sensitive to stimulus conditions. To gain a better insight into mechanisms of contextual modulation, we asked what patterns of modulation are invariant of the nuance of stimulation. We uncover the invariants by measuring maps of modulation across the full range of modulating parameters and then compare the empirical maps with predictions of models of neural interactions. We studied contextual modulation using two luminance gratings ("flankers") and a "probe" positioned between the flankers. The probe was either distributed (luminance grating) or localized (line). We measured the probe visibility for a wide range of flanker contrasts (C) and spatial frequencies (SF). First, we used distributed probes and obtained a bivariate map of probe contrast threshold in the coordinates of C and SF. The facilitatory effect of context formed well-defined "islands" in the map, i.e., facilitation was tuned to both C and SF. The nonmonotonic effect of flanker contrast could only arise in a nonlinear system, for example in the process of stimulus encoding or when the distributed neural activity is collapsed to the binary decision variable. Second, we attempted to bypass the decision nonlinearity using a localized probe (line). Line contrast threshold varied as a function of location between the flankers and it depended on flanker contrast, similar to the results with distributed probes. The results suggest the encoding origin of the nonlinearity. We use results of empirical mapping to constrain a model of contextual modulation in terms of the canonical inhibition-stabilized neural network (ISN). We show that a chain of canonical ISN nodes is tuned to SF (arXiv:1410.4237) producing lateral interactions that are also tuned to flanker SF and C, similar to our results.

26.4105 Statistics of boundary, luminance, and pattern information predict occluding target detection in natural backgrounds

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Detecting spatial patterns is a fundamental task solved by the human visual system. Two important constraints on detection performance are the variability that is found in natural scenes and the degradation of the image that occurs due to optical blurring and non-homogenous sampling of the retinal ganglion cell (RGC) mosaic across the visual field. Furthermore, most previous studies of detection performance have been conducted in the fovea with additive targets. However, image cues are different with occluding targets so these studies may not generalize well to occluding targets presented in the periphery. Here, we report eccentricity thresholds (eccentricity for 70% correct detection) for four different occluding targets presented in natural backgrounds at varying, but known, distances from

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the fovea. The luminance and contrast of the targets was fixed, and precise experimental control of the statistics (luminance, contrast and similarity) of the natural backgrounds was obtained using a novel method known as constrained scene sampling (Sebastian, Abrams & Geisler, submitted). Next, we describe a first-principles model, limited by known physiology of the human visual system and by the statistics of natural scenes, to compare with the pattern of observed thresholds. First, target-present and target-absent images are filtered by a modulation transfer function that approximates the optics of the human eye. Second, RGC responses are simulated by blurring and downsampling the optically-filtered image in a fashion consistent the midget RGCs at each retinal eccentricity. The model then combines luminance, pattern, and boundary information in the target region to predict detectability across the visual field. We show that a weighted combination of these three cues predicts the pattern of thresholds observed in our experiment. These results provide a characterization of the information that the human visual system is likely to be using when detecting occluding objects in the periphery.

26.4106 **Detecting, Localizing and Correcting Exposure-Saturated Regions Using a Natural Image Statistics Model** Zeina Sinno[1,2,3](zeina@utexas.edu), Christos Bampis[1,2,3], Alan Bovik[1,2,3]; [1]Laboratory for Image and Video Engineering (LIVE), [2]Department of Electrical and Computer Engineering, [3]The University of Texas at Austin

While the human visual system is able to adapt to a wide range of ambient illumination levels, cameras often deliver over- and/or under-exposed pictures of consequently low quality. This is particularly true of low-cost CMOS-based mobile camera devices that pervade the market. Towards finding a way to remediate this problem, we study the characteristics of poorly-exposed image regions under a natural scene statistics model with a goal of creating a framework for detecting, localizing and correcting overand/ or under-exposed pictures. Poorly-exposed picture regions are detected and located by analyzing the distributions of bandpass, divisively normalized pictures under a natural scene statistics model. Poor exposure levels lead to characteristic changes of the empirical probability density functions (histograms) of the processed pictures. This can be used to trace potential images saturated by over- or under exposure. Once detected, it is possible to ameliorate these distortions. If a stack (sequence) of maps of the same scene is available taken at different exposure levels, then it is possible to correct poorly exposed regions by fusing the multiple images. Experiments on multi-exposure datasets demonstrate the effectiveness of such an approach which suggests its potential for real-time camera tuning and post-editing of multiply exposed images.

SUNDAY MORNING TALKS

ATTENTION: SELECTION AND MODULATION

Sunday, May 21, 8:15 - 9:45 am
Talk Session, Talk Room 1
Moderator: Anne Sereno

31.11, *8:15 am* **Investigating the neural correlates of automatic attention shifts in electroencephalography** Merle Ahrens[1,2](m.ahrens.1@research.gla.ac.uk), Domenica Veniero[1], Monika Harvey[2], Gregor Thut[1]; [1]Insititute of Neuroscience and Psychology, University of Glasgow, UK, [2]School of Psychology, University of Glasgow, UK

Previous research has highlighted posterior oscillations in the alpha-band to play a key role in goal-directed (top-down) visuospatial attention (Foxe&Snyder 2011). However, the oscillatory signatures of automatically driven (bottom-up) alerting and orienting of attention remain uncertain. Likewise, it is unclear to what extend these automatic processes are influenced by top-down components, such as mid-frontal oscillatory activity in the theta-band. These oscillations are associated with cognitive control processes activated when goal directed bias over habitual responses is needed (Cavanagh&Frank 2014). Here, we employed electroencephalography to investigate the neural correlates of automatic attentional engagement in healthy participants. We utilized an exogenously cued dot detection task. Following a non-predictable spatial cue or no-cue, targets were presented at cued or non-cued positions at four different cue-target delays (ranging from 105.8-705.8ms), known to induce initial attentional benefits and later inhibition-of-return (IOR). This experimental manipulation allowed us to investigate both automatic alerting (cue vs. no-cue independent of space) and automatic (re)orienting (cued vs. uncued position) at early and later stages of spatial attention processes. Between-subject correlations of reaction times (RTs) and alpha-power revealed that individuals who showed an early alerting effect (faster RTs in cue vs. no-cue) exhibited stronger alpha-band desynchronization over occipital regions before target onset (independent of space and hemisphere). Notably, the same analysis also revealed a negative influence of mid-frontal theta activity (P300) over alerting, where individuals with higher central theta-power displayed slower RT. Interestingly, central theta-increases also negatively affected later spatial components of automatic attention (i.e. IOR), where IOR was abolished in individuals with higher theta power. These results suggest an interplay between top-down processes and automatic attention mechanisms, in accordance with cognitive control overriding reflexive processes. They highlight the need to control for the engagement of higher-order computations in order to better understand the neural correlates of automatic processes in isolation.

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31.12, *8:30 am* **Alpha and gamma neurofeedback reinforce control of spatial attention** Yasaman Bagherzadeh[1](yasaman@mit.edu), Daniel Baldauf[1], Benjamin Lu[1], Dimitrios Pantazis[1], Robert Desimone[1]; [1]McGovern Institute for Brain Research, Massachusetts Institute of Technology,

Previous studies have shown that alpha synchrony is linked with suppression of information processing, whereas gamma frequency is associated with attention to targets. To determine whether alpha and gamma synchrony play a causal role in the control of spatial attention, we designed a MEG neurofeedback task to train subjects to increase an asymmetry of oscillatory power between the left and right parietal cortex (alpha in Exp1 or gamma in Exp2). During neurofeedback trials a Gabor pattern was presented in the center of the screen, with its contrast modulated according to a real time measure of the hemispheric asymmetry in the alpha (or gamma) range. We tested the effects of these oscillatory changes on both behavioral performance in a free viewing task and on visual evoked potentials recorded from visual cortex. Twenty healthy subjects participated in the study. They were divided into two groups, a left and a right training group, depending on the feedback direction of the hemispheric asymmetry. We found that subjects were able to control the asymmetry between the left and right hemispheres in the frequency range of interest in both training directions. Increasing alpha in one hemisphere lead to reduced visually evoked responses (Exp1) while increasing gamma in one hemisphere lead to enhanced evoked responses (Exp2). Hemispheric asymmetry in the alpha band resulted in attentional bias in the free viewing task by reducing the number of fixations in the contralateral hemifield. The results support the idea that alpha and gamma synchrony play reciprocal roles in the control of spatially directed attention.

31.13, *8:45 am* **Accounting for attention in perceptual decisions and confidence** Rachel Denison[1,2](rachel.denison@nyu.edu), William Adler[2], Marisa Carrasco[1,2], Wei Ji Ma[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Purpose: To make optimal perceptual decisions, observers must take into account the uncertainty inherent in their sensory representations. Humans take into account sensory uncertainty caused by stimulus factors such as low contrast. However, it is not known whether humans take into account sensory uncertainty caused by internal factors such as low attention. Here we asked whether humans adjust their perceptual decisions and confidence reports to account for attention-dependent uncertainty. Methods: Twelve observers performed an orientation categorization task, in which the two categories had the same mean orientation but different standard deviations, and reported both categorization (category 1 or 2) and confidence (4-point scale) on each trial. In this task, unlike a traditional left vs. right orientation discrimination, the optimal choice boundaries depend on orientation uncertainty. We manipulated endogenous (voluntary) covert spatial attention trial-by-trial using a central precue pointing to one of four possible stimulus locations (valid and invalid precues) or to all locations (neutral precue). Four stimuli appeared briefly on each trial, and a response cue indicated which stimulus should be reported. We used generative modeling of the experimental data and model comparison to determine the influence of attention on decision and confidence boundaries. Results: Attentional cueing affected performance accuracy—highest for valid, intermediate for neutral, lowest for invalid—verifying that the attentional manipulation of orientation uncertainty was successful. Decision and confidence boundaries shifted under different levels of attention in a way indistinguishable from optimal. The Fixed model, in which observers do not adjust for attention-dependent uncertainty, fit the data poorly. The Bayesian model and two heuristic models, in which observers adjust boundaries according to parametric decision rules, performed similarly, and substantially better than the Fixed model. Conclusion: Perceptual decision-making responds flexibly to uncertainty related to attention, an internal state. This flexibility should improve perceptual decisions in everyday vision.

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31.14, *9:00 am* **Task performance in covert, but not overt, attention correlates with early ERP laterality** Rinat Hilo[1](rinathil@post.tau.ac.il), Marisa Carrasco[2], Shlomit Yuval-Greenberg[1,3]; [1]School of Psychological Sciences, Tel Aviv University, [2]Department of Psychology and Center for Neural Science, New York University, [3]Sagol School of Neuroscience, Tel Aviv University

Background. Visual performance decreases with target eccentricity. To compensate for such decrements, we move our eyes to target locations (overt attention) or attend to these locations without accompanying eye-movements (covert attention). Both overt and covert attention enhance perceptual performance, but it is undetermined whether they do so to the same extent. Here we compared overt and covert attentional enhancements using electrophysiological and behavioral measurements. Methods. ERP and eye-tracking were measured in 16 participants. On each trial, a central directional cue (100% valid) pointed to the left or right. In most (80%) trials a task-irrelevant probe appeared bilaterally 300-500ms post cue. Only trials with probes were analyzed and the ERP signal was examined relative to probe-onset at time zero, to reveal ongoing attentional enhancement while

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observers attended to the cued location. In half the trials, a target Gabor-patch was presented 300-500ms after the probe in the cued location. To indicate target detection, observers responded either by pressing a button (covert condition) or by shifting the eyes (overt condition). Results. Mean visual sensitivity was significantly higher for the covert than the overt condition, resulting from same hit rate and lower false alarm. Laterality of the ERP responses (difference between contralateral and ipsilateral channels relative to the cue) was found for both overt and covert attention shifts, around the P1 component (90-135ms) and the N2 component (185-300ms). ERP laterality in the P1 time-range was positively correlated across participants with task performance on the covert, but not the overt, task. Conclusion. Covert attention can be more effective than overt attention. Overt attention is a natural dual-task requiring both shifting of attention and performing a target-directed action. Covert attention requires only shifting of attention without a goal-directed action, and therefore can be easier to perform and is more correlated with early attentional ERP components.

Acknowledgement: The Binational United States-Israel National Science Foundation, grant 2013356.

31.15, *9:15 am* **Effect of Apparent Depth in Peripheral Target Detection in Driving under Focused and Divided Attention** Jiali Song[1](songj16@mcmaster.ca), Patrick Bennett[1], Allison Sekuler[1], Hong-Jin Sun[1]; [1]Psychology, Behaviour & Neuroscience, McMaster University

The ability to detect events in the visual periphery is crucial to driving safely. The useful field of view (UFOV) task provides an index of the spatial extent of peripheral vision under focused and divided attention. Previous research reported reduced UFOV at greater perceived distances in driving (Andersen et al., 2011; Pierce & Andersen, 2014); however, these studies used long stimulus durations, making it difficult to compare directly with the traditional UFOV task (Sekuler & Ball, 1988; Sekuler, Bennett & Mamelak, 2000), which correlates with critical aspects of driving performance (Owsley et al., 1998; Ball et al., 1993). Furthermore, previous studies on the depth effect in driving assessed performance only under divided attention. The current study adapts the traditional 2D UFOV task to a computer-rendered 3D environment to examine whether apparent depth affects the detection of brief peripheral targets, under focused and divided attention, and with target retinal image size matched across depth. In the central task, participants tried to maintain a constant distance from a speed-varying lead car, indicated when the lead car's image size matched that of a surrounding size-invariant box. In the peripheral task, participants detected targets appearing at one of several possible locations on the left or right side at two apparent distances, implied via simulated forward motion and pictorial cues. The central and peripheral tasks were completed separately under focused attention, and then, simultaneously under divided attention. We tested 24 participants and found they responded more accurately to near than far targets at larger eccentricities under focused and divided attention. Another 24 participants, tested in a second experiment with different target appearance probabilities, showed similar results. Thus, our data suggest that apparent depth influenced the detection of briefly flashed peripheral targets. These results are generally consistent with previous research, and have important implications for understanding the mechanisms modulating the UFOV.

31.16, *9:30 am* **Attention to shape enhances shape discrimination in AIT neural population coding but attention to space does not modulate location discrimination in LIP of macaque monkeys.** Anne Sereno[1](anne.b.sereno@uth.tmc.edu), Sidney Lehky[2]; [1]Dept. of Neurobiology and Anatomy, Univ. of Texas Health Science Center in Houston, [2]Computational Neurobiology Laboratory, Salk Institute

We studied attentional effects for stimulus shape and location in anterior inferotemporal cortex (AIT, ventral stream) and lateral intraparietal cortex (LIP, dorsal stream). Monkeys performed two delayed-match-to-sample tasks. Stimuli were identical in both tasks, but in one the monkey attended to sample shape (shape attention task) and in the other to sample location (location attention task). There was also a third passive task in which the monkey maintained central fixation while the same stimuli were presented in the same locations. We examined data from all shapes at the most effective location (shape representations), or all locations using the most effective shape (location representations). At the single cell level, there was a broad range of attentional gain factors for stimulus shape and location in both brain areas. At the population level, responses of all neurons to each shape or each location formed a response vector. Mean distance between response vectors for different shapes was greater (more distinctive) in AIT than LIP, while mean distance between locations was greater (more distinctive) in LIP than AIT. We determined the effect of different attentional conditions on mean distance between response vectors for all shapes or all locations. In AIT, mean response distance between shapes was significantly larger under the shape attention task compared to the location attention task. In contrast, in LIP, mean response distances for locations were not significantly different between the two attention tasks. Even when changes in mean responses were factored out, multidimensional scaling still showed significant task differences in AIT but not LIP, indicating that attention was globally distorting neural representation spaces only in AIT. Despite single-cell attentional modulations in both areas, we suggest that attentional modulations of population representations may be weaker in the dorsal stream because it must maintain more veridical representations for visuomotor control.

Color and Light: Color vision

Sunday, May 21, 8:15 - 9:45 am
Talk Session, Talk Room 2
Moderator: Michael Crognale

31.21, *8:15 am* **Metameric Mismatching in Natural and Artificial Reflectances** Arash Akbarinia[1](arash.akbarinia@cvc.uab.es), Karl Gegenfurtner[2]; [1]Centre de Visió per Computador, Universitat Autònoma de Barcelona, [2]Abteilung Allgemeine Psychologie, Justus-Liebig-Universität

The human visual system and most digital cameras sample the continuous spectral power distribution through three classes of receptors. This implies that two distinct spectral reflectances can result in identical tristimulus values under one illuminant and differ under another – the problem of metamer mismatching. It is still debated how frequent this issue arises in the real world, using naturally occurring reflectance functions and common illuminants. We gathered more than ten thousand spectral reflectance samples from various sources, covering a wide range of environments (e.g., flowers, plants, Munsell chips) and evaluated their responses under a number of natural and artificial source of lights. For each pair of reflectance functions, we estimated the perceived difference using the CIE-defined distance ΔE2000 metric in Lab color space. The degree of metamer mismatching depended on the lower threshold value l when two samples would be considered to lead to equal sensor excitations ($\Delta E < l$), and on the higher threshold value h when they would be considered different. For example, for l=h=1, we found that 43.129 comparisons out of a total of 6×107 pairs would be considered metameric (1 in 104). For l=1 and h=5, this number reduced to 705 metameric pairs (2 in 106). Extreme metamers, for instance l=1 and h=10, were rare (22 pairs or 6 in 108), as were instances where the two members of a metameric pair would be assigned to different color categories. Not unexpectedly, we observed variations among different reflectance databases and illuminant spectra with more frequency under artificial illuminants than natural ones. Overall, our numbers are not very different from those obtained earlier (Foster et al, JOSA A, 2006). However, our results also show that the degree of metamerism is typically not very strong and that category switches hardly ever occur.

31.22, *8:30 am* **Quickly-forming, shape-dependent memory biases in color perception** Maria Olkkonen[1,2](maria.olkkonen@durham.ac.uk), Toni Saarela[1]; [1]Institute of Behavioural Sciences, University of Helsinki, [2]Department of Psychology, Durham University

Background: Both long-term and short-term experience with object color affects color perception. Memory colors (typical colors of familiar objects such as fruit) draw perceived color towards them. Central-tendency bias (CTB) occurs when the perceived color of a stimulus held in memory shifts towards the average color of recent stimulus history. We studied how these biases develop: First, what is the time-course of CTB? Second, do memory colors start developing immediately upon exposure to shape-dependent hue distributions? Methods: Observers compared the hue of two stimuli in a 2IFC task. A 2-second delay separated the reference (first) and test (second) intervals. Two visually distinct 2D-shapes, "softy" and "spiky", were used. Both had five reference values ranging from blueish to greenish in CIELAB color space; softies were on average greener and spikies bluer but had one color in common. Reference and test were always the same shape except for the common reference color, for which reference and test were of different shape. On each trial, observers indicated whether the test appeared bluer or greener than the reference. A 1-1 staircase procedure controlled the test hue for each reference to track its perceived color. Results: In within-shape judgments, perceived color of the extreme references was biased towards the middle hues, consistent with CTB. This effect formed quickly: it appeared during the first 20 trials and was very prominent after 50-100 trials. Across-shape judgments showed, unexpectedly, a repulsive effect: The "softy" reference was matched by a bluer "spiky", and "spiky" reference by a greener "softy". Conclusion: Memory biases of perceived color develop rapidly and can be shape-dependent. The observed attractive and repulsive biases can be explained by shape-specific adaptation to color range, whereby hues are normalized with respect to the hue distribution separately for the two shapes, followed by a central-tendency bias.

Acknowledgement: Supported by the Academy of Finland grant 287506.

31.23, *8:45 am* **Color-ambiguity Matching** Steven Shevell[1,2,3](shevell@uchicago.edu), Wei Wang[1,2]; [1]Institute for Mind and Biology, University of Chicago, [2]Department of Psychology, University of Chicago, [3]Department of Ophthalmology & Visual Science, University of Chicago

Classical color matching reveals physically different lights that appear identical. For example, a mixture of 550+670 nm lights appears identical to 580 nm light viewed alone. The explanation is that the physically different lights result in identical neural responses so must be indistinguishable. Note this explains why the lights match each other, though not their perceived hue. This principle is extended here to neural representations of color that are ambiguous and thus perceptually unstable: two lights with identical but ambiguous neural representations match each other even though their hue can vary. This is color-ambiguity matching. METHODS/RESULTS: Ambiguous chromatic neural representations were generated using a form of interocular-switch rivalry (aka stimulus rivalry; Logothetis, Leopold & Sheinberg, Nature,1996). Two binocularly rivalrous chromaticities were swapped between the two eyes about 7 times/second. This resulted in a sustained percept for over 1.5 sec (>10 eye swaps) of one color and then the other color. Further, two such ambiguous representations, one above a fixation point and one below it, usually were the same color (far above chance, $p < 0.001$). Although their color changed regularly, both appeared the same. Importantly, a control with an ambiguous representation above fixation and a nonrivalrous stable representation below showed that the stable color (below) did not directly facilitate the same color above. CONCLUSION: Two separate stimuli that generate identical but ambiguous neural representations become grouped, even though the resulting color is unstable. Like classical color matching, the neural representations establish a match without specifying the perceived hue, which fluctuates over time. Note grouping by identical ambiguous representations occurs prior to perceptual resolution of the neural ambiguity. This is unlike the typical assumption that the color seen determines grouping, as in resolution of the correspondence problem in ambiguous apparent motion in which grouping by color establishes motion direction.

Acknowledgement: Supported by NIH EY-026618

31.24, *9:00 am* **Facilitation of color discrimination by verbal and visual cues** Lewis Forder[1](forder@wisc.edu), Gary Lupyan[1]; [1]Department of Psychology, University of Wisconsin-Madison, Madison, WI, USA

People can distinguish millions of hues, but often refer to colors categorically using linguistic terms that denote large regions of color space. We hypothesized that color names warp color representations making them more categorical such that simply hearing a color name would induce more categorical color perception. We tested this hypothesis by examining how cuing color verbally (Exps. 1, 2) or visually (Exp. 3) affected people's ability to distinguish colors at various locations in color space. We predicted that hearing a color name (e.g., "blue") would transiently facilitate perceptually discriminating between blues and non-blues. If the label activates a more categorical color representation it should also, counterintuitively, help in distinguishing more typical blues from less typical blues, but not highly typical blues and slightly less typical blues. We conducted three experiments (N=85) to test these hypotheses. After locating each participant's focal colors and color boundaries, we tested color discrimination using a 4-alternative odd-one out task maintaining a constant perceptual distance between target and non-targets in CIELUV space. Hearing a color name of the target immediately prior to the color display improved overall performance from M=79.6% to M=86.1% ($z=9.6$, $p < .0001$) compared to trials on uncued trials. Verbal cues facilitated visual discrimination only when the target and non-targets spanned a category boundary, and in discriminating more from less typical colors. Exp. 2 showed that color names improved discrimination performance even when categories were blocked making the cues redundant. Exp. 3 showed that facilitation from visual color cues was significantly smaller than from verbal cues, suggesting that words are especially effective in activating categorical color representations. Overall, our results suggest that processing color names affects the ability to distinguish colors and that the extent to which we perceive colors categorically may be flexible and depend on the current task

31.25, *9:15 am* **Individual differences in hue scaling suggest mechanisms narrowly tuned for color and broadly tuned for lightness** Kara Emery[1](karaemery@nevada.unr.edu), Vicki Volbrecht[2], David Peterzell[3], Michael Webster[1,4]; [1]Graduate Program in Integrative Neuroscience, University of Nevada, Reno, [2]Department of Psychology, Colorado State University, [3]Clinical Psychology Doctoral Program, College of Psychology and Holistic Studies, John F. Kennedy University, [4]Department of Psychology, University of Nevada, Reno

Individual differences in color appearance judgments are large and reliable among color-normal observers, but for poorly understood reasons. In our recent factor analyses of hue-scaling functions (Emery et al. 2017ab, Vision Research), we found that the differences depended on multiple processes each tuned to a narrow range of stimulus hues, consistent with a multiple-channel or population code mediating color appearance, but not classic opponency. In the present work, we extended this analysis outside the equiluminant plane by sampling the colors of increments and decrements, to assess the tuning for both hue and lightness. Stimuli included 12 chromatic angles at 30-deg intervals along a circle of fixed contrast in the cone-opponent plane. Each was shown at five lightness levels (0.5, .7, 1, 1.4 and 2 times the 20 cd/m2 luminance of the gray background). The stimuli were displayed in random order in a uniform 2-deg field and were repeatedly pulsed until observers recorded the perceived proportion of red, green, blue, or yellow in the hue. Individual settings for 14 observers were factor-analyzed with PCA and Varimax rotation. The analysis revealed approximately seven systematically-tuned factors (i.e. with moderate to high loadings on 2 or more adjacent stimuli). Together these accounted for >80% of the total variance. The factors approximated our previous analyses in exhibiting narrow and unipolar tuning for chromatic angle. Across the lightness levels, however, the factors tended to show consistent loadings, suggesting for example, that there were strong correlations between how an individual scaled the hues of increments and decrements. No clear univariant factor emerged that was specific to increments or decrements, even though the average perceived hue varied with lightness. This pattern confirms that many independently varying dimensions determine inter-observer differences in hue judgments, and suggests that these dimensions co-vary (operate similarly) across a range of lightness levels.

Acknowledgement: EY-10834

31.26, *9:30 am* **Color vision for flight control in Drosophila** Kit Longden[1](longdenk@janelia.hhmi.org), Michael Reiser[1]; [1]HHMI Janelia Research Campus, 19700 Helix Drive, Ashburn, VA 20147, USA

The circuitry of color vision in Drosophila is a classic system for understanding the development of neural circuitry and is among the best described for any animal. Flies can learn to discriminate different wavelengths of light, but it is not known what they use color vision for in spontaneous behavior. We have explored how the processing of the wavelength of light contributes to three different kinds of flight behavior. To do this, we developed a novel ultraviolet and green projector system to display wide-field visual stimuli. We measured the flight control responses of tethered flies by optically recording changes in wing stroke amplitude. First, flies can stabilize the horizon even when the intensities of the different wavelengths are matched so that they provide no luminance contrast. This is achieved by combining wavelength-sensitive phototaxis and color-blind motion vision to stabilize the scene. Second, during looms the steering responses are color-blind, but the wing beat frequency varies with the intensity of ultraviolet light. Third, during flight towards an attractive object, a single vertical stripe, the responses are color blind. Taken together, our results show how

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the wavelength of light can influence multiple aspects of flight attitude and control, and allow the operation of color vision circuitry to be investigated in the context of natural behaviors.

Acknowledgement: HHMI Janelia Research Campus

Spatial Vision: Crowding and statistics

Sunday, May 21, 10:45 am - 12:30 pm
Talk Session, Talk Room 1
Moderator: Steve Dakin

32.11, *10:45 am* **Cortical magnification factor of human V2 predicts individual susceptibility to letter-crowding** Steven Dakin[1,2](s.dakin@auckland.ac.nz), Samuel Schwarzkopf[3,4], Geraint Rees[3,5], Catherine Morgan[2], Elaine Anderson[1,3,5]; [1]UCL Institute of Ophthalmology, University College London, [2]School of Optometry & Vision Science, University of Auckland, [3]UCL Institute of Cognitive Neuroscience, University College London, [4]Experimental Psychology, University College London, [5]Wellcome Trust Centre for Neuroimaging, University College London

Our peripheral vision is fundamentally limited by our inability to recognise objects when they appear within "clutter", a phenomenon known as crowding. Although widely studied, the cortical locus of this phenomenon remains unclear. This is in part because it is difficult to distinguish neural activity arising from a change in the stimulus (e.g. from introducing clutter) from activity associated with the resulting crowding. Here we overcome this by quantifying individual differences in susceptibility to crowding and correlate this with parameter estimates of cortical architecture, assessed using population receptive field (pRF) analysis of human fMRI data. We report that a simple psychophysical index of 'crowding susceptibility ' (the ratio of acuity for an isolated letter versus a crowded letter) is highly correlated with individual estimates of cortical magnification factor (CMF) in visual areas V2 and V3. This is strong evidence that V2/V3 plays a crucial role in setting the spatial scale of crowding and, as has been noted in several complementary psychophysical and computational studies, is consistent both with the receptive field (RF) and shape-encoding properties of cells within these areas.

Acknowledgement: Wellcome Trust, University of Auckland

32.12, *11:00 am* **Suppressive stimulus interactions in visual cortex reflect the critical spacing in crowding** Leili Soo[1](leilisoo@abdn.ac.uk), Ramakrishna Chakravarthi[1], Plamen Antonov[1], Søren Andersen[1]; [1]School of Psychology, University of Aberdeen, UK

Crowding is a phenomenon in which peripheral object recognition is impaired by the close proximity of irrelevant stimuli. Currently, the neural processes underlying object recognition and its failure in crowding are not well understood. Research examining the neural implementation of visual attention has found that stimulus processing in visual cortex is suppressed by the presence of nearby stimuli. Could the breakdown of object recognition seen in crowding be explained by such flanker induced suppression of target processing in the visual cortex? To answer this question, we assessed cortical processing of a target object as a function of flanker presence and distance to the target while participants performed a target orientation discrimination task. Flankers and targets flickered at different frequencies to elicit steady-state visual evoked potentials (SSVEPs), which allow for the assessment of cortical processing of each of the concurrently presented stimuli. Target identification accuracy and target elicited SSVEP amplitudes decreased with decreasing target-flanker separations. Additionally, we fitted psychometric curves to both behavioral data and target elicited SSVEP amplitudes in order to determine the spatial extent of interference ('critical spacing'). The cortical and behavioral critical spacing estimates closely mirrored each other. Unexpectedly, however, the presence of any flankers, even those far beyond either critical spacing, dramatically decreased SSVEP amplitudes elicited by the target, relative to the unflanked condition. We conclude that suppressive stimulus interactions between targets and flankers in the visual cortex may underlie the perceptual phenomenon of crowding. Further, the finding that flankers far outside the traditional critical spacing can suppress target processing might potentially explain the large variability in observed critical spacing across different experimental conditions if it is the case that behavioral effects are observable only when cortical interference reaches a threshold.

Acknowledgement: BBSRC EASTBIO

32.13, *11:15 am* **Cortical distance determines the perceptual outcomes of crowding** John Greenwood[1](john.greenwood@ucl.ac.uk), Joseph Danter[1], Rhiannon Finnie[1]; [1]Experimental Psychology, University College London

In peripheral vision, object recognition is disrupted by clutter. This crowding effect typically causes target and flanker objects to appear more alike (assimilation). However, tilt contrast effects also increase in peripheral vision, causing target and flanker objects to appear more dissimilar (repulsion). Although repulsion dominates in the parafovea with large target-flanker separations, assimilation increases with higher eccentricities and/or smaller separations (Mareschal, Morgan & Solomon, 2010). The common factor has been argued to be cortical distance: assimilation occurs when flankers are close to the target within retinotopic maps, while flankers at greater distances induce repulsion. Here we test this proposal with two psychophysical manipulations that dissociate cortical and physical distance. Observers (n=8) judged the orientation of a target Gabor (clockwise/counter-clockwise of vertical), flanked by two Gabors oriented either clockwise or counter-clockwise of vertical. We first manipulate cortical distance via the arrangement of target-flanker elements: because cortical magnification is higher along the radial dimension (extending from fixation), radially-positioned flankers will be cortically closer to the target than tangential/iso-eccentric flankers. Accordingly, we observe far more assimilation errors with radial flankers, while tangential flankers predominantly induce repulsion errors. We next manipulate cortical distance by presenting stimuli in the upper and lower visual fields. Because the upper-field representation is compressed (Fortenbaugh, Silver & Robertson, 2015), target-flanker separations will be effectively reduced relative to the lower field. Accordingly, for stimuli with the same physical eccentricity and target-flanker separation, we observe far greater assimilation in the upper than the lower visual field. Individual differences in visual-field size are also correlated with these assimilation rates. Our results suggest that cortical distance is a key determinant of the perceptual outcomes of crowding. By combining models of crowding and tilt contrast, we suggest that the compulsory pooling of orientation-selective population responses can provide a common mechanism for these effects.

Acknowledgement: Funded by the UK Medical Research Council

32.14, *11:30 am* **Towards a Unifying Model of Crowding: Model Olympics** Adrien Doerig[1](adrien.doerig@gmail.com), Aaron Clarke[2], Greg Francis[3], Michael Herzog[1]; [1]1 Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, [2]Laboratory of Computational Vision, Psychology Department, Bilkent University, Ankara, Turkey, [3]Department of Psychological Sciences, Purdue University, USA

In crowding, perception of an object deteriorates in the presence of nearby elements. Obviously, crowding is a ubiquitous phenomenon since elements are rarely seen in isolation. Up to date, there exists no consensus on how to model crowding. In previous experiments, it was shown that the global configuration of the entire stimulus needs to be taken into account. These findings rule out simple pooling or substitution models and favor models sensitive to global spatial aspects. In order to further investigate how to incorporate these aspects into models, we tested a large number of models, using a database of about one hundred stimuli. As expected, all local models fail. Further, capturing basic regularities in the stimulus does not suffice to account for global aspects, as illustrated by the failures of Fourier analysis and textural models. Our results highlight the importance of grouping to explain crowding. Specifically, we show that a two-stage model improves performance strongly. In this model, first, elements are segregated into groups and, second, only elements in the same group interfere with each other. The model must integrate information across large parts of the visual field.

32.15, *11:45 am* **How do we count at a glance?** Richard Murray[1](rfm@yorku.ca), Kevin DeSimone[1,2], Minjung Kim[1]; [1]Department of Psychology and Centre for Vision Research, York University, [2]Department of Psychology and Center for Neural Science, New York University

Sunday AM

Many studies have examined the ability of humans and other animals to rapidly perceive the approximate number of elements in a scene, but there has been little work on what computation underlies this ability. To address this question we measured psychophysical decision spaces for number judgements. Observers judged whether a reference stimulus or test stimulus contained more dots. The reference stimulus had fixed area and density on all trials. The test stimulus had a wide range of areas and densities across trials. From 3,300 trials we created a 2D plot showing the observer's probability of choosing the test stimulus as more numerous, as a function of its log area and log density. In fifteen such plots (five observers with three reference stimuli each; 49,500 trials total), fitted decision curves showed that number judgements were based on log-area plus log-density, i.e., they were monotonically related to true number (consistent with Cicchini et al., 2016). We fitted a generalized additive model (GAM) to this data, and found that number judgements were based on almost perfectly logarithmic transformations of area and density, again demonstrating that number judgements are tightly linked to true number. There is debate about whether number judgements are based on number, or on low-level properties like density. We implemented an ideal observer model that simply counts stimulus elements, and also Dakin et al.'s (2011) bandpass-energy model of number perception, and ran them in the same experiment as human observers. Surprisingly, both models' decision spaces were practically the same as human observers'. Thus decision spaces are highly informative in that they reveal the stimulus properties that guide observers' number judgements, but they are less useful for discriminating between current competing models. We will suggest that number adaptation aftereffect experiments have greater potential to choose between current models.

Acknowledgement: NSERC, CFI

32.16, *12:00 pm* **Multidimensional Normalization is Optimal for Detection in Natural Scenes** Wilson Geisler[1](w.geisler@utexas.edu), Stephen Sebastian[1], Jared Abrams[1]; [1]Center for Perceptual Systems, University of Texas at Austin

A fundamental everyday visual task is to detect specific target objects within a background scene. Under natural conditions, both the properties of the background and the amplitude of the target (if present) are generally different on every occasion. To gain some understanding of detection under such natural conditions we determined the amplitude thresholds in natural images of a matched-template detector, as a function of the three local background properties: luminance, contrast, and phase-invariant similarity to the target. We found that threshold (which is equal to the standard deviation of the template response) is a linear separable function (the product) of all three dimensions—"multidimensional Weber's law." This fact poses a serious problem for detecting targets under natural conditions, where both the properties of the background and the target amplitude are uncertain. Specifically, good performance requires a different decision criterion on the template responses for each possible combination of background properties. However, we show that divisively normalizing the template (feature) responses by the product of the locally estimated luminance, contrast, and similarity creates a distribution of template responses that is normal with a standard deviation of 1.0, independent of the background properties. Thus, for any desired false-alarm rate the optimal hit rate is obtained with a single decision criterion, even under maximum uncertainty. This is just the sort of normalization (gain-control) observed early in the visual system for the dimensions of luminance and contrast, and perhaps for similarity. In psychophysical experiments, we show that human performance is consistent in detail with this normalized matched template observer (which has only a single efficiency parameter). We argue that the rapid and local neural gain-control mechanisms, and the psychophysical laws of masking, are most likely the result of evolving a near optimal solution to detection in natural backgrounds under conditions of high uncertainty.

Acknowledgement: NIH grants EY024662 and EY11747

32.17, *12:15 pm* **Perceptual straightening of natural video trajectories** Olivier Henaff[1,2](henaff@cns.nyu.edu), Robbe Goris[4], Eero Simoncelli[1,2,3]; [1]Howard Hughes Medical Institute, [2]Center for Neural Science, New York University, [3]Courant Institute of Mathematical Sciences, New York University, [4]Center for Perceptual Systems, University of Texas at Austin

In a video of an object moving or deforming over time, the vector of pixels follows a complex high-dimensional trajectory. Yet human observers understand such trajectories and immediately recognize the persistence of the object. Inspired by the "untangling hypotheses" (DiCarlo & Cox, 2007), we propose that the visual system builds a representation of temporally contiguous images that is less curved, such that linear operations are sufficient to capture object persistence. To test this hypothesis, we estimated the curvature of a set of natural image sequences in the pixel and perceptual domains. Pixel-domain curvature is computed as the angle between high-dimensional vectors corresponding to differences between consecutive frames. Perceptual curvature is computed by first estimating an internal trajectory that best accounts for the discriminability of pairs of frames under brief, peripheral presentation in a sequential ABX paradigm. Specifically, we formulated an observer model that measures distances in a fixed-dimensional perceptual space, then maximize the likelihood (over the entire data set for an observer) of the location of each frame within that space. The curvature of this perceptual trajectory is then computed as for the pixel-domain trajectory. Consistent with our hypothesis, we found that perceptual curvature of natural videos was systematically reduced relative to pixel-domain curvature. This suggests that the visual system non-linearly distorts incoming information so as to linearize natural image sequences. It follows that image sequences that are straight in the pixel domain should generally be curved perceptually. We tested this prediction by estimating the perceptual curvature of synthetic image sequences that fade linearly from an initial to a final frame. In this unnatural case, perceptual curvature was systematically larger than pixel-domain curvature. Together, these results demonstrate the existence of non-linear operations used by the visual system to build simple representations of naturally occurring temporal image transformations.

Acknowledgement: Howard Hughes Medical Institute

3D PERCEPTION

Sunday, May 21, 10:45 am - 12:30 pm
Talk Session, Talk Room 2
Moderator: Julie Harris

32.21, *10:45 am* **Rendering correct blur** Steven Cholewiak[1](steven.cholewiak@berkeley.edu), Gordon Love[2], Martin Banks[1]; [1]Optometry & Vision Science, UC Berkeley, Berkeley, California, USA, [2]Department of Physics, Durham University, Durham, UK

Blur occurs naturally when the eye is focused at one distance and an object is present at another distance. Vision scientists and computer-graphics (CG) engineers often wish to create display images that reproduce such depth-dependent blur, but their method is incorrect for that purpose. Their method appropriately takes into account the scene geometry, pupil size, and focus distances, but does not take into account the optical aberrations of the person who will view the resulting display images. We developed a method that, by incorporating the viewer's optics, yields displayed images that produce retinal images close to those in natural viewing. Here we concentrate on the effects of longitudinal chromatic aberration. This aberration creates different chromatic effects in the retinal image for object farther vs nearer than current focus. Our method handles this correctly. Observers viewed scenes with depth-dependent blur. They viewed stimuli monocularly in three conditions: 1) A plane at one physical focal distance but various amounts of blur, rendered conventionally, simulating planes at different distances; 2) a plane at one focal distance but blur rendered using our method, creating natural depth-dependent chromatic effects in the retina; 3) multiple planes at different focal distances, so blur is created in natural fashion in the subject's eye. We measured accommodation and perception of depth order in these conditions. Accommodation was not driven with the conventional blur-rendering method, but it was driven with equal accuracy by real and simulated changes in focal distance when simulated changes were based on our method. We also found that depth-order judgments were random with conventional rendering of blur, but were quite accurate when the blur was created naturally in the eye or with our rendering method. Thus, creating display images that produce retinal images like those that occur naturally enables accommodation and facilitates depth perception.

32.22, *11:00 am* **Human surface tilt estimation in natural and artificial 3D scenes**

Seha Kim[1](sehakim@sas.upenn.edu), Johannes Burge[1]; [1]Department of Psychology, University of Pennsylvania

Estimating 3D surface orientation (slant and tilt) is an important task for sighted organisms. Previous studies have focused on artificial stimuli. Here, we study human surface tilt estimation with both artificial and natural stimuli. We obtained a large database of stereo-images of natural scenes providing rich image cues to surface orientation; precisely co-registered range data provided groundtruth tilt, slant, and distance at each pixel. We created a set of artificially-textured (plaids, pink noise) planar surfaces matched to the tilt, slant, distance, and contrast of the natural stimuli. We sampled natural and artificial stereo-image stimuli based on groundtruth tilt. 3600 stereo-patches were randomly selected; 150 for each groundtruth tilt. Human observers viewed natural and artificial surfaces through a small aperture (1deg). Observers indicated their tilt estimate with a mouse-controlled probe. Tilt estimation with natural and artificial stimuli differs markedly. Performance in natural scenes is much less accurate and less precise than in artificial scenes. Natural tilt estimates are strongly affected by a tilt prior whereas artificial tilt estimates are unaffected. These differences can largely be attributed to non-planar surface structure of natural scenes. Remarkably, despite these differences, the natural and artificial tilt estimates are equally good indicators of groundtruth tilt. Moreover, human performance is tightly predicted (including trial-by-trial errors) with zero free parameters by an ideal observer model for tilt estimation in natural scenes (Burge & Geisler, 2016). The ideal observer reports the Bayes-optimal minimum-mean-squared error (MMSE) tilt estimates given three local image cues (luminance, texture, disparity gradients). The strong similarities between human and ideal performance suggest that the human visual system is optimized to make optimal use of image information from local areas of natural scenes. These findings show that despite biases and overall imprecision, human 3D tilt estimation is a lawful perceptual process governed by priors and local measurements.

32.23, *11:15 am* **A data-driven approach to learning 3D shape**

Sven Eberhardt[1](sven2@brown.edu), Daniel Schiebler[1], Drew Linsley[1], Thomas Serre[1]; [1]Cognitive Linguistic & Psychological Sciences Department, [2]Brown University

Knowledge of the 3D structure of objects supports a variety of behaviors that animals depend on in their daily lives, from navigating through their environments to understanding their surroundings at every stop along the way. Multiple pictorial depth cues, including texture, boundary, shading and lighting, support the recovery of 3D shape information. Substantial work has gone into the development of computational models of 3D shape perception from each individual cue, but these efforts have yielded relatively little insight into the underlying neural computations. To investigate this question, we use a data-driven approach to train deep convolutional networks (DCNs) to learn to estimate local 3D surface orientations from 2D images of common objects as well as pseudo objects composed of primitive geometric shapes. We leverage modern computer graphics methods to generate large-scale near photo-realistic datasets of these stimuli under a large variety of viewing conditions (including multiple materials, light sources, viewpoints, etc), together with pixel-level 3D shape annotations and category labels (for common objects). We demonstrate that DCNs learn robust representations of surface orientations. We further investigate the tuning properties of receptive fields shaped by this learning process systematically – in an effort to characterize the underlying computational strategy used by the networks. Interestingly, we also find that object recognition accuracy is significantly improved when using 3D shape prediction as an auxiliary task while training for object categorization. These findings provide computational evidence for existing object recognition theories that highlight the role of surfaces for object recognition and provide empirical validation for a data-driven approach to modeling visual perception. Combined with the release of our large dataset of annotated images of 3D objects, we hope that these results will spur renewed interest for 3D approaches to object recognition from both the biological and computer vision communities.

Acknowledgement: DARPA young faculty award (N66001-14-1-4037), NSF early career award (IIS-1252951)

32.24, *11:30 am* **The Veiled Virgin Project: Causal layering of 3D shape**

Flip Phillips[1](flip@skidmore.edu), Roland Fleming[2]; [1]Neuroscience & Psychology, Skidmore College, [2]Department of Psychology, Justus-Liebig-University of Giessen

The form of a three dimensional object depends on a number of factors. Nonrigid, laminar materials, such as cloth and skin, take a form that is determined by their physical properties as well those of an underlying object. For example, clothes adopt the global shape of the person wearing them but also exhibit wrinkles, folds, and other features due to the way fabric drapes and self-organizes. Artists and sculptors are intimately aware of this interaction and have learned to depict compelling representations of figures swathed in cloth using solid lumps of marble (e.g., Giovanni Strazza's "Veiled Virgin"). Inspired by such sculptures, we sought to understand how the visual system decomposes a single visible surface relief into distinct causal layers, distinguishing which features are due to the underlying object, and which due to overlying textile. Here we present a series of experiments testing observers' ability to divine the underlying causes of a 3D object's form. We made three irregular landscape surfaces, which we then draped with an opaque lightweight cloth in various configurations. Using 3D scanning we obtained geometric descriptions of the underlying surfaces and the various drapings, which we then used to render ideal opaque Lambertian surfaces of the composite shapes. Using a painting interface presented on an iPad, subjects directly indicated regions of causation on the stimuli (i.e., which ridges appeared to be caused by the underlying landscape, and which by the overlying textile). This allowed us to directly compare the subjects' markings with the geometric features of the stimuli. We show that subjects were strikingly good at separating the underlying structure from the effects of the covering material. This shows that the visual system can separate shape into distinct causes, much like it can decompose image intensities into transparent layers.

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32.25, *11:45 am* **Dynamically deformable volume completion: A new class of visual shape illusions**

Peter Tse[1](peter.tse@dartmouth.edu); [1]Dept. Psychological and Brain Sciences, Dartmouth College

Here I introduce a remarkable new class of visual illusions that reveal that binocular presentation can give rise to the percept of volumes that appear to vary smoothly across discrete depths in binocularly fused images, when in fact only two binocular disparities are discretely defined between corresponding contour elements of the inducing elements. Surfaces are filled in from one depth layer's visible contours to another layer's within virtual contours interpolated on the basis of good continuation (e.g. Tse, 1999ab) between visible contour portions. When there are two or more surface-propagating contour segments, the propagated surfaces can merge and possess a depth and perceived surface curvature consistent with all visible contour segments, despite the absence of local disparity cues at interpolated surface locations far from any visible contour. In addition, I introduce a new class of dynamic volume completion, where constant image elements can link across a gap between two or more objects, leading to the perception of illusory volumes that deform non-rigidly as the rigid image inducers move. These new demonstrations provide further evidence that volume completion is not dictated solely by contour relatability constraints, but is instead a dynamic process of volumetric construction that takes into account dynamic cues to object shape even in the absence of any contour relatability whatsoever. These demonstrations place constraints on the surface and volume generation processes that construct our 3D world, yet cannot be easily explained by existing models of visual processing. These demonstrations suggest that there may be a specialized system that completes 3D spatial surface/volume layout for objects. Such an 'object mesh cell' system, if one exists, would not only interpolate portions of surfaces that are not visible, but also self-occluded portions of surfaces, such as the hidden sides of a volume.

32.26, *12:00 pm* **Perceptual integration of depth cues is facilitated by inhibitory processing in dorsal visual cortex**

Reuben Rideaux[1](rr513@cam.ac.uk), Andrew Welchman[1]; [1]Department of Psychology, School of Biological Sciences, University of Cambridge

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Human perception makes use of multiple visual cues that are integrated to achieve robust and accurate estimates of 3D structure. A region of the dorsal visual cortex (V3B/KO) is intricately involved in depth cue integration (Ban et al, 2012, Nature Neuroscience, 15, 636-643), although the precise nature of the neural computations involved is unknown. Here we test the importance of the balance between excitation and inhibition for cue integration, using MR spectroscopy (MRS) to provide correlative evidence and transcranial direct current stimulation (tDCS) to provide causal evidence. Participants discriminated the slant of an inclined plane, where slant was defined by (i) texture, (ii) disparity, (iii) congruent combinations of disparity and texture or (iv) incongruent (conflicting) combinations. We found that perceptual judgments for incongruent cues were associated with higher concentrations of the inhibitory neurotransmitter GABA in a voxel centred over V3B/KO ($r=.77$, $N=18$), and that this relationship was task/region specific; that is, there was no relationship between GABA and single or congruent cue slant judgements nor incongruent judgements and GABA concentration in control (sensorimotor/V1) voxels. We then manipulated cortical excitability around V3B using tDCS ($N=12$). Reducing excitability disrupted integration of both congruent ($p=.001$) and incongruent ($p=.01$) cues: slant discrimination was worse for combined cues (but not single cues) under cathodal tDCS. These effects were task and region specific and not due to changes in eye movements. These results indicate the importance of inhibitory processing underlying the integration of different depth cues. Further, we show that reducing excitability impedes the summation of congruent cues, and alters re-weighting of incongruent cues. These findings are broadly consistent with a gain mechanism model of cue integration (Ohshiro et al, 2011, Nature Neuroscience, 14, 775-782).

Acknowledgement: Wellcome Trust

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32.27, *12:15 pm* **Encoding and decoding in neural populations with non-Gaussian tuning: the example of 3D motion tuning in MT** Kathryn Bonnen[1,3](kathryn.bonnen@utexas.edu), Alexander Huk[1,2,3], Lawrence Cormack[1,2,3]; [1]Center for Perceptual Systems, University of Texas at Austin, [2]Psychology, College of Liberal Arts, University of Texas at Austin, [3]Neuroscience, College of Natural Sciences, University of Texas at Austin

From visual orientation in primate V1 to wind velocity in cricket cercal cells, neuronal tuning almost always follows a bell-shaped function. While this is a comforting empirical regularity, here we report that a basic visual property (3D motion direction) is encoded with tuning that is staggeringly non-Gaussian -- characterized by distinct plateaus separated by steep cliffs, i.e. `terraces'. To understand the source and implications of the unconventional tuning form, we first examined how this "terraced" encoding scheme might arise from tuning to basic 2D motion cues. We found that canonical forms of frontoparallel velocity tuning interact with the geometry of 3D space and binocularity to yield these 3D direction tuning shapes. The resulting encoding model takes MT's canonical log-gaussian tuning to monocular velocities, adds the two monocular responses, and then performs the requisite trigonometric transformations to extract 3D direction from the differential velocities in the two eyes. 3D direction tuning was predicted well ($r>.5$ for 75% of neurons) by this simple additive, trigonometric model. Then we considered how 3D direction can be decoded from such tuning curves. Modeling estimation and discrimination of 3D directions revealed three surprising insights: a) Ocular dominance likely underlies coarse direction discrimination, rather than differential velocity tuning across the eyes; b) Estimation of 3D direction is more precise for motions roughly towards/away than motions closer to frontoparallel; c) If 3D motion perception relies on the MT tuning, performance on 3D motion direction discrimination tasks should change dramatically as a function of viewing distance. In summary, our model of 3D direction encoding in MT captures the drastically non-Gaussian tuning curves observed empirically, and further examines the consequences of these for decoding and perception. This framework should generalize to encoding/decoding of other environmentally-realistic features; e.g. how retinal orientation relates to 3D slant and tilt.

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Motion: Depth and Models

Sunday, May 21, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

33.3001 A model for spatial integration of pattern and 3D motion in MT neurons

Pamela Baker[1,2](pmbaker@uw.edu), Wyeth Bair[1,2]; [1]Department of Biological Structure, University of Washington, [2]Washington National Primate Research Center

Pattern motion sensitivity is a critical response property in MT, and the spatial scale of pattern motion integration in MT neurons provides a key constraint for MT models. Experimental studies have examined how pattern selectivity deteriorates for "pseudoplaids" where the component gratings of the plaid are spatially separated within the MT RF and varied in size (Majaj et al., 2007; Kumbhani et al., 2015). They concluded that pattern motion is computed at a spatial scale ~1/3 of the MT RF. Mechanisms proposed to account for this include V1 direction-tuned normalization, which may arise from surround suppression, or spatially-local computational subunits in MT dendrites. Previous MT models omitted spatial integration or were not image-computable, precluding the testing of alternative hypotheses. We developed an image-computable modeling framework to build pattern-selective MT units (Baker and Bair, 2016), and extended this framework to include V1 inputs with RFs distributed across visual space and summed to produce MT RFs ~5x the diameter of V1 RFs. We tested the hypothesis that the apparent subunit size of spatial integration is determined by V1 monocular opponency, the same mechanism that explains loss of pattern sensitivity for dichoptic plaids (Baker and Bair, 2016). In model units with V1 opponency and tuned normalization, we reproduced the main results of Majaj and Kumbhani, without including explicit spatial subunits. In particular, pattern sensitivity in our MT units degraded when component gratings were shown in a 2x2 grid lacking spatial overlap, but with finer 4x4 grids, pattern sensitivity began to recover. We tested our spatial integration model using binocularly-presented pseudoplaids with opposite motion in each eye, making the novel prediction that 3D-motion tuning remains robust even for pseudoplaids where monocular pattern sensitivity is lost. We are now implementing physiologically-plausible V1 surround suppression to test alternative hypotheses for how the spatial subunit is determined.

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33.3002 Linking normative models for natural tasks and subunit models of neural response

Johannes Burge[1](jburge@sas.upenn.edu), Priyank Jaini[2]; [1]Department of Psychology, University of Pennsylvania, [2]Department of Computer Science, University of Waterloo

Understanding how the nervous system exploits task relevant properties of sensory stimuli to perform natural tasks is central to the study of perceptual systems. Recently, a Bayesian ideal observer method was developed for task-specific dimensionality reduction called Accuracy Maximization Analysis. AMA returns the encoding filters (receptive fields) that extract the most useful stimulus features for specific estimation and categorization tasks. Unfortunately, in its original form, AMA's compute time is quadratic in the number of stimuli in the training set, rendering it impractical for large scale problems without specialized computing resources. Here, we develop AMA-Gauss, a new more practical form of AMA that reduces compute time from quadratic to linear in the number of stimuli by incorporating the assumption that the conditional filter responses are Gaussian distributed. First, we verify the expected compute time decreases with two fundamental tasks in early vision: binocular disparity estimation and retinal speed estimation. Second, we demonstrate that the task-specific receptive fields returned by AMA-Gauss closely approximate the properties of receptive fields in cortex. Third, we show that the Gaussian assumption is justified for all three tasks with natural stimuli and biologically realistic contrast normalization. Fourth, we show that quadratic computations are required to compute the likelihood function and posterior probability distribution over the latent variable. Fifth, we make explicit the formal similarities between AMA-Gauss and the Generalized Quadratic Model (GQM), a recently developed method for neural systems identification. Together, these results provide a normative explanation for why energy-model-like (i.e. quadratic) computations account well for the response properties of neurons involved in these tasks. These developments should help accelerate research with natural stimuli, deepen our understanding of why classic descriptive models have proved successful, and improve our ability to evaluate results from subunit model fits to neural data.

33.3003 Comparison of horizontal vergence responses to changing disparity and inter-ocular velocity differences

Martin Giesel[1](mg232@st-andrews.ac.uk), Julie Harris[1], Alexandra Yakovleva[2], Alex Wade[3], Marina Bloj[4], Anthony Norcia[2]; [1]School of Psychology & Neuroscience, University of St Andrews, UK, [2]Department of Psychology, Stanford University, USA, [3]Department of Psychology, University of York, UK, [4]School of Optometry and Vision Sciences, University of Bradford, UK

A percept of motion in depth (MID) can be generated from two types of binocular cues: changes of disparity over time (CD) or inter-ocular velocity differences (IOVD). The relative contribution of these two cues to another important binocular function—vergence eye movements—is poorly understood. Stevenson et al. (1994) reported vergence responses to dynamic random-dot stereograms (RDS) containing only CD information. More recently Sheliga et al. (2016) showed that IOVD stimuli also drive the vergence system, albeit weakly. Here we compare the relative potency of IOVD and CD cues as inputs to the vergence system in the same participants. We used RDS stimuli portraying MID either towards or away from the observer with either a ramp or step motion profile. In the 'ramp' condition, the dots moved for 2s at 1deg/s, for 'step' the dots made an instantaneous 1deg step. Vergence eye movements were recorded in response to four types of MID stimuli: RDS that isolate IOVD (both anti-correlated, aIOVD, and de-correlated, dIOVD), isolate CD (dynamic RDS) or that contained both cue types (FULL). Stimuli were presented on a LG OLED TV passive 3D display. Vergence eye movements were measured using an EyeLink II. We measured the slopes of vergence, once underway, to provide an estimate of the velocity of the vergence response. We found high vergence velocities for both FULL and CD conditions. We also found responses to aIOVD and dIOVD cues, but they were clearly weaker than the responses to FULL and CD. No systematic differences were found between aIOVD and dIOVD. IOVD thus provides an input to vergence, but under our conditions of measurement, it is a weak one. Additionally, for FULL and CD we found evidence for gain differences in the vergence response depending on the direction of the movement in depth.

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33.3004 Fat-tailed propagation noise model of visual object tracking

Byeong-Hee Gwak[1](qudgml50@unist.ac.kr), Hanan Mohamed[1], Oh-Sang Kwon[2]; [1]School of Life Sciences, UNIST, Ulsan, South Korea, [2]Department of Human Factors Engineering, UNIST, Ulsan, South Korea

Background: According to the optimal tracking model of visual motion perception (Kwon, Tadin, & Knill, 2015), the visual system integrates noisy sensory inputs with the prediction of a forward model that reflects natural dynamics to estimate the states of a moving object continuously. The model provides a unifying account of several visual illusions, such as motion induced position shift, curveball illusion, and peripheral slowing of perceived speed. However, illusory perception of flicker-defined motion (Mulligan & Stevenson, VSS demo, 2014) provides a counterexample against the prediction of the model. The flicker-defined motion appears to jump, even when it moves continuously. The current version of the optimal tracking model, a Kalman filter model, cannot generate jumping percepts of a continuously moving object regardless of the parameter values. Simulation results: The propagation noise of the tracking model represents the visual system's assumption of the random changes of velocity over time. The current model assumes that the propagation noise follows a Gaussian distribution. However, various movements observed in nature follow fat-tailed distribution, rather. (Kleinberg, 2000; Sims et al., 2008). We built a model that assumes fat-tailed distribution as a propagation noise, and numeri-

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cally simulated the performance of the model using particle filtering. The simulation results are qualitatively consistent with the observed illusory percepts. First, the model can account for the three visual illusions mentioned above (motion induced position shift, curveball illusion, peripheral slowing of perceived speed). Second, the model predicts jumping percepts given the flicker-defined motion as sensory inputs when the target moves smoothly. Furthermore, the model predicts that the jumping frequency increases as the speed of the target motion increases, which is consistent with the qualitative observation. Conclusions: Simulation results show that fat-tailed propagation noise model can account for a wider range of perceptual phenomena than the current optimal tracking model. It suggests that the visual system assumes fat-tailed propagation noise reflecting objects' movements often observed in nature.

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33.3005 **The influence of contour geometry on structure-from-motion: from symmetry to parallelism** Xiaoli He[1,2](xiaoli.he@rutgers.edu), Jacob Feldman[1,2], Manish Singh[1,2]; [1]Department of Psychology, Rutgers University - New Brunswick, [2]Center for Cognitive Science, Rutgers University - New Brunswick

Structure-from-motion (SFM) studies have shown that observers have vivid 3D percepts in dynamic dot displays that are projectively consistent with 3D rotation. Empirical and computational studies have focused on the motion profile of the dots, with only a few reports that people can still perceive 3D structures when the occluding contours are projectively inconsistent with 3D rotation (Ramachandran et al. 1988; Froyen et al., JOV2013; Tanrikulu et al., VSS2014, VSS2015). These studies suggest that occluding contour geometry may influence SFM percepts. We previously showed that SFM displays with fixed, asymmetric contours (inconsistent with 3D rotation) still generate vivid 3D percepts (He et al., VSS2016). Given the importance of skeletal models in shape representation, we focus here on the spectrum from symmetry to parallelism. Stimulus shapes consisted of two vertically oriented sine curves with different relative phases (0, pi/3, 2pi/3, pi). Contour geometry remained fixed within each dynamic display; hence only the symmetric shapes are projectively consistent with rigid rotation, and the displays get progressively less consistent with increasing deviation from symmetry. Dots moved horizontally with different speed profiles, varying from constant speed to a cosine speed profile (projectively consistent with 3D rotation in depth). In a method of constant stimuli, observers judged whether each display looked like a solid 3D object. Observers perceived vivid 3D structure in parallel displays, which are grossly inconsistent with 3D rotation, even with as little as 60% cosine motion. Parallel display did require a higher proportion of cosine motion to perceive 3D structure than symmetric displays, but the difference was surprisingly small. The results demonstrate that projective consistency is less important in SFM than conventionally assumed. Contour geometry and dot motion both play roles as well, in a way that sometimes overrides projective consistency.

Acknowledgement: 433903

33.3006 **Perception of Depth-Order from Motion: An Electroencephalographical Study** Ashley Kalle[1](akalle@augusta.edu), Jennevieve Sevilla[2,3], Jay Hegdé[2,3,4]; [1]Department of Psychological Sciences, College of Science and Mathematics, Augusta University, [2]Brain and Behavior Discovery Institute, Medical College of Georgia, Augusta University, [3]James and Jean Culver Vision Discovery Institute, Medical College of Georgia, Augusta University, [4]Department of Ophthalmology, Medical College of Georgia, Augusta University

When one visual object moves behind another, it provides a sense of which object is closer to, or farther from, the viewer in depth. This percept of relative depth is referred to as depth-order from motion (DFM). While DFM is relatively well characterized from a psychophysical perspective, the neural mechanisms of DFM remain largely unclear. To help characterize the dynamic aspects of DFM perception at a high temporal resolution, we conducted a dense-array (256-channel) electroencephalography (EEG) study of DFM in human subjects (N = 8; 7 females). Random dot stimuli (10o dia, 8o/s) that either elicited strong depth-order percepts (DFM stimuli) or did not (null stimuli) were presented, one per trial, in randomized order. The two sets of stimuli were otherwise identical, including in terms of velocity, average luminance, contrast, and motion energy. Subjects maintained fixation throughout the 4000 ms stimulus presentation and reported their percept as soon as possible. To help characterize the electrophysiological signatures of the reported DFM percept, we analyzed the evoked potential during a 500 ms period immediately preceding the subjects' behavioral response. Incorrect DFM reports were associated with large positivities (≥ 20 μv) over much of the frontal lobe and somewhat smaller, but strikingly widespread negativities over much of the parietal, temporal, and occipital lobes. Compared to DFM stimuli, null stimuli elicited modest negativities over the lateral aspect of the occipito-parietal cortex. Source localization studies indicated, consistent with our previous fMRI findings (Hegdé & Chen, J Vis, 2012), that the strongest sources lay in the ventromedial frontal cortex, anterior temporal cortex, and lateral occipito-temporal cortex. Both evoked potentials and localized sources showed considerable interhemispheric asymmetry. Together, these results identify electrophysiological signatures of key aspects of DFM perception and, given EEG's portability, also highlight the potential feasibility of using EEG to monitor DFM under real-world conditions.

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33.3007 **The Visual Features of Smoke** Max Kinateder[1](max.kinateder@dartmouth.edu), Tobias Pfaff[2], Emily Cooper[1]; [1]Dartmouth College, [2]Avametric

Visual motion cues can be created by self-motion, by solid moving objects, and by non-solids such as gases or fluids. We wanted to determine what types of motion cues are available to the visual system when viewing gaseous, as opposed to solid, stimuli. In particular, we focus on cues available for estimating the motion-in-depth of smoke and its time-to-contact with an observer. While much is known about the visual cues available for estimating the motion-in-depth of solid objects (e.g., looming/optical expansion, binocular disparity, interocular velocity differences), little is known about how robust and reliable these cues are for estimating the motion of stimuli that change shape, size, and density in the environment. Principles from fluid dynamics can account for the 3D motion of smoke, but do not directly indicate what information is available to the human visual system. Thus, we examine the visual cues present in moving smoke and compare these to the cues for a similarly moving solid object. We provide descriptive statistics about looming, motion coherence, speed and angular movement for a range of stimuli, including videos of actual smoke and computer generated simulations. Our analysis shows that similar motion cues are present for solids and smoke, but provide different information about the distance and speed at which solids and smoke are moving. For example, looming may provide less information about motion direction for smoke than for solids. However, transparency provides a potential cue for smoke that is not present for solids. When relying on these cues, our results suggest that observers may perceive equivalently moving solids and non-solids as having different trajectories. Because typical observers likely have substantially more experience with solid motion, such perceptual differences may have implications for how people respond to smoke, for example, in building fires.

33.3008 **Speed discrimination for real-world motion in depth** Abigail Lee[1](aril@st-andrews.ac.uk), Justin Ales[1], Julie Harris[1]; [1]School of Psychology and Neuroscience, University of St. Andrews

Several studies have shown that precise speed discrimination is possible for both lateral motion and motion in depth. Typically, studies ask observers to discriminate between different constant retinal speeds. However, in everyday life, when an object approaches us in depth at a constant speed in the world, the image of that object on the retina accelerates as the object grows closer. Here, we compare naïve observers' ability to discriminate a change in speed using lateral motion or motion in depth, constant retinal speed or constant world speed, and 'slow' (4.5 - 48 arcmin/second) or 'fast' (7.5 - 121 arcmin/second) speed conditions. Importantly, measuring speed discrimination can be confounded by distance and duration cues in the stimulus. For example, if the duration of the stimulus is fixed, faster objects within the stimulus will travel further. We therefore developed a novel experimental design allowing us to control against the use of distance and duration cues. We found no significant difference between thresholds for constant real-world and constant retinal speed conditions, with average speed change thresholds of around 32% for both. However, we found that there was a significant difference in thresholds between the lateral motion and motion in depth conditions. Thresholds for motion in depth were worse than those for lateral motion (around 37% and 28% respectively). We also found that the average threshold for fast speed conditions was significantly better than for the slow conditions (around 30% and 35% respectively). These results show that naïve observers are as precise in judging the speeds of stimuli with constant retinal and constant world speed. To our knowledge, this is the first study to show for 3D motion that observers can be as sensitive to changes in real-world speed (that result in accelerating retinal motion) as changes in the speed of constant retinal motion.

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33.3009 Time to Contact Estimation in Virtual Reality Dinesh Pai[1](pai@cs.ubc.ca), Robert Rolin[1], Jolande Fooken[2], Miriam Spering[2]; [1]Computer Science, University of British Columbia, [2]Ophthalmology and Visual Science, University of British Columbia

INTRODUCTION: Virtual Reality (VR) headsets that can display binocular stimuli are now widely available to the general public. Many tasks and scenarios presented in VR involve dynamic visual objects. Yet, no systematic studies have been conducted to investigate motion perception in VR. We conducted three experiments to quantify the perception of looming motion in VR, using judgment of time to contact (TTC), and to evaluate the effectiveness of interventions to improve accuracy of TTC estimates. METHODS: Observers viewed a virtual baseball stadium from the perspective of a batter standing in the batter's box, using an Oculus Rift VR headset. Simulated balls were pitched at the observer. In each trial the ball was visible for a brief duration and moved at one of four constant speeds, between 20 and 83 mph. The ball trajectory was either fully visible or disappeared after 1/4, 1/2, and 3/4 of the trajectory. Observers judged TTC by button press. RESULTS: Observers (n=10) generally underestimated ball speed in both VR and non-VR settings. TTC accuracy systematically improved with increasing presentation duration and decreasing speed in both settings. Next we investigated three interventions (in n=19) to improve the accuracy of TTC estimates in VR. These manipulated different perceptual cues that inform speed perception: (1) The speed of the model ball increased. (2) The size of the model ball increased as it approached the observer, providing monocular cues of increased speed. (3) The vergence angle increased, providing binocular cues of increased speed. All three interventions improved TTC estimation accuracy, with better correction at lower speeds. CONCLUSION: The findings indicate that there is systematic underestimation of speed in VR, which can be effectively corrected by different interventions.

Motion: Flow and Illusions

Sunday, May 21, 8:30 am - 12:30 pm

Poster Session, Banyan Breezeway

33.3010 Effects of motion picture frame rate on material and texture appearance Robert Allison[1,2](allison@cse.yorku.ca), Yoshitaka Fujii[1,3], Laurie Wilcox[1,4]; [1]Centre for Vision Research, York University, [2]Dept. of Electrical Engineering and Computer Science, York University, [3]Faculty of Design, Kyushu University, [4]Dept. of Psychology, York University

It is now possible to economically film and present movies at much higher frame rates (HFR) than the traditional 24 frames per second (fps). The higher fidelity enabled by HFR should allow viewers to see more detail. In this experiment we asked viewers (N = 31) to assess the impact of motion on their ability to discern detail in fabrics and costume ornamentation. Stimuli were four garments hung on a hanger. These were filmed at all combinations of two resolutions (2k and 4k), three frame rates (24, 48 and 60 fps), and two shutter angles (180° and 358°). On each trial, participants viewed two clips of the same garment on a 4k monitor. The first clip showed the garment while stationary. The second showed the same outfit while the hanger was either moved up or down in the frame. Observers rated the quality of the moving clip relative to the stationary clip in terms of degradation of sharpness. As expected, we found that the fabric detail became noticeably less distinct when in motion. Increasing the frame rate significantly increased perceived detail. However, shutter angle had a small effect except at the lowest frame rate where increased shutter angle was associated with more impairment. The effect of frame rate was expected because, as frame rate is increased, temporal resolution is enhanced and motion blur and aliasing are avoided. Given the relatively weak effects of shutter angle, we conclude that aliasing and judder were stronger determinants of perceived detail than motion blur. Our results suggest that naïve observers perceive enhanced detail in fabrics and costumes in HFR film. Improved perception of detail could underlie both the positive and negative reactions to HFR film, depending on the nature of the content and whether it lends itself to such high fidelity.

Acknowledgement: NSERC Canada

33.3011 Short motions look faster than long ones Stuart Anstis[1](sanstis@ucsd.edu), Juno Kim[2]; [1]Psychology, UC San Diego, CA, [2]Psychology, U of New South Wales, Australia

Motion looks faster when it moves along a short compared with a long path (Ryan & Zanker 2001), but little is understood about why this occurs. We examined possible causes of this effect, including scaling effects, landmarks, edge transients, nonlinear judgments of time and space, and temporal frequency judgments (J.F. Brown 1931). We used a random-dot pattern that translated horizontally over a sixteenfold range of speeds, ranging from 0.34 to 5.5°/s; it seemed to move 50% faster when viewed through a shorter (0.5°) rather than a longer (4.5°) aperture in the form of a horizontal slot, and twice as fast when viewed through a vertical compared with a horizontal slot (regardless of its actual speed). We also found that transparent, superimposed orthogonal motions could undergo separate speed illusions dependent upon slot shape. Nearby stationary landmarks did not affect perceived speed. We varied rectangular aperture lengths over a tenfold range; manipulated the size, shape, orientation of the apertures, and used limited-lifetime dots and transparent dot fields moving in different directions.

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33.3012 Effects of contrast polarity and binocularity on global motion discrimination Lanya Cai[1](tcai@sunyopt.edu), Benjamin Backus[1]; [1]Graduate Center for Vision Research, SUNY College of Optometry

Primate vision exhibits a "light-dark asymmetry" originating with ON and OFF channels in the retina. Neurophysiology and psychophysics show a processing speed advantage for darks (Komban et al. 2011, J Neurosci). We looked for a corresponding "dark benefit" in global motion perception. Performance during global motion perception in random-dot kinematograms (RDKs) depends on stimulus duration, so when stimulus duration is very short, a dark benefit in early vision could lead to better efficiency for dark dots as compared to light dots. We therefore measured percent coherence thresholds for dark-dot and light-dot RDKs, on a grey background, at four stimulus durations: 0.33, 0.23, 0.14, and 0.07 sec. Viewing was monocular or binocular, to test whether binocularity interacts with dot polarity. Four normally sighted observers were tested in a forced-choice net motion discrimination task using a stereoscope. Threshold was estimated using a 3-down-1-up staircase procedure. Stimuli contained 100 dots. Two-frame dot motion at 30Hz was used to minimize selective tracking. Dot polarity and stimulus duration were constant within blocks, while trials from the monocular and binocular viewing conditions were intermixed. As expected performance was better (lower percent coherence thresholds) at long stimulus durations. Surprisingly, all observers performed better with light dots than with dark dots of the same contrast. The neural mechanism behind this advantage is unknown. For light dots, performance in the monocular and binocular conditions was similar, consistent with Cai, Yuan, and Backus (VSS 2015). However, for dark dots, two highly practiced observers performed better when dots were presented binocularly; this unexpected interaction could result from left-eye/right-eye asymmetry of input to global motion mechanisms.

33.3013 Evidence of a Contrast Induction Field for Peripherally Viewed Motion Stimuli Aaron Clarke[1](aaron.clarke@bilkent.edu.tr), Duygu Savcı[1]; [1]1. Departments of Psychology & Neuroscience, Bilkent University, Ankara, Turkey

Illusions have been leveraged to reveal the mechanisms of perception since at least the time of the Gestalt psychologists of the early 1920's. Here, we characterize a new motion illusion that, to the best of our knowledge, has never been reported in the literature and is not explainable by known mechanisms. In this illusion, a peripherally viewed black square translates across a gray background. The translating square induces a field of dark areas above and below it and in the trailing tail, but not in front of it. This field of darkness vanishes when viewing the square foveally. We characterize the strength and spatial extent of the field by flashing a small probe dot

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at various positions around the square and having subjects perform a luminance increment detection task on the dot while fixating on a static peripheral target. We measure luminance increment detection thresholds using the method of constant stimuli in a two-interval forced-choice task. Weber's law dictates that luminance increment detection thresholds increase with increasing background intensity. Consistent with this, we find that the probe dot has lower increment detection thresholds in regions around the square perceived to be darker than it does in the regions perceived to be lighter, even though the backgrounds are physically the same. Thus, the illusory dark regions induce real differences in luminance detection thresholds around the square. We discuss potential mechanisms to explain this phenomenon.

Acknowledgement: TÜBİTAK 2236 Co-Funded Grant, Project No. 116C037

33.3014 **The Double-drift Illusion Affects Both the Perception of Where the Target IS and the Memory of Where it WAS.** Sydney Gilbert[1, 2, 3](gilbert.sydney@gmail.com), Daryn Blanc-Goldhammer[2, 3], Paul Dassonville[2, 3]; [1]Robert D. Clark Honors College, University of Oregon, [2]Department of Psychology, University of Oregon, [3]Institute of Neuroscience, University of Oregon

In the double-drift illusion, the perceived trajectory of a moving Gabor is biased by its internal local motion (Tse & Hsieh, 2006; Lisi & Cavanagh, 2015). It remains unclear whether this distorted trajectory is caused by erroneous perception of the current location of the stimulus, erroneous memory of its previous locations, or both. Blanc-Goldhammer et al. (VSS 2016) asked observers to compare the location of the trajectory's start (or end) to a probe presented just before (or after) a single sweep of a double-drift stimulus, and demonstrated that the illusion caused a small distortion of the perceived starting location (biased in a direction opposite the local motion) and a larger (~3X) distortion of the perceived ending location (biased in the same direction as the local motion). In the present experiment, we assessed the change in the observer's memory of the trajectory's starting location, by asking the observer to compare the onset location with a probe that could be presented before or after motion onset (-250, 0, 250, 500 or 1000ms). Participants maintained fixation in the center of the screen while a Gabor containing leftward, rightward, or no internal motion traveled upward for 500ms in the periphery; the global motion of the stimulus was adjusted for each observer to offset the effects of the illusion so that the perceived trajectory was purely vertical. For probes presented 250ms before motion onset, the local motion induced a small but significant distortion of the perceived starting location. This bias grew significantly with later probe presentations, reaching a plateau for delays of 250ms or longer. These findings suggest that at least a portion of the distortion in the trajectory of a double-drift stimulus is caused by a bias in the memory of its earlier locations, which are pushed in a direction opposite the local motion.

33.3015 **Proprioceptive self-localization modulated by vection** Michiteru Kitazaki[1](mich@cs.tut.ac.jp); [1]Department of Computer Science and Engineering, Toyohashi University of Technology

We perceive illusory self-motion when a coherent motion is presented in a large visual field (vection), usually in the opposite direction to the visual motion (eg, Kitazaki & Sato, Perception 2003). Our body posture is influenced by the large-field visual motion to sway in the opposite direction to vection. However, an aftereffect of vection on a proprioceptive self-localization has not been investigated. Illusory body ownership such as the out-of-body experience drifts the proprioceptive self-localization toward the illusory body (Lenggenhager, Tadi, Metzinger & Blanke, Science 2007). If vection induces a shift of perceived self-body similarly to the out-of-body experience, we predict that the self-localization after vection would drift in the opposite direction to vection (negative aftereffect). In Experiment 1, twenty subjects observed a radially expanding or contracting flow of a cloud of 100 or 200 random dots on a head-mounted display. Latency and duration of vection were measured during 60s stimulus presentation. After the visual stimulus, they performed a self-localization task; the subjects were moved back at a random distance without sight, and asked to walk to the original location by themselves without sight. All conditions were repeated 10 times in random orders. We found that vection was stronger with more dots (p=.0083), and the self-localization drifted in the opposite direction to vection regardless of the number of dots (p=.0181). In Experiment 2, twenty subjects observed a jittering or non-jittering radially expansion or contraction of 230 dots, and performed identical tasks. We found that the self-localization drifted in the opposite direction to vection regardless of jitter (p=.0179), while we did not find a jitter effect on vection. To conclude, the proprioceptive self-localization drifted in the opposite direction to vection after the vection-stimulus presentation. It is suggested that vection would affect the perception of self-body location, and induce its aftereffect.

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33.3016 **A model of optic flow parsing as error in prediction** Oliver Layton[1](Laytoo2@rpi.edu), Brett Fajen[1]; [1]Department of Cognitive Science, Rensselaer Polytechnic Institute

While many models emphasize feedforward processing as a driving factor in visual perception, others have posited a more central role for feedback (Carpenter & Grossberg, 1987; Hochstein & Ahissar, 2002). In particular, predictive coding theories have posited that feedback carries predictions about how sensory signals should appear and feedforward signals transmit the error between the sensory array and prediction (prediction error; Friston, 2010). We propose that this view may shed light on the important problem that the visual system faces as humans move through the environment – that of object motion perception during self-motion. Although the pattern of motion on the retina reflects the sum of self-motion and object motion, humans perceive object motion relative to the stationary world (Rushton & Warren, 2005). This implicates a mechanism whereby the visual system factors out the self-motion component from the retinal optic flow (Layton & Fajen, 2016; Warren & Rushton, 2009). We suggest that world-relative object motion perception could emerge through interactions between areas MT and MST that attempt to minimize the discrepancy between the retinal flow and predicted flow pattern consistent with the observer's self-motion. In our model, MT matches feedforward optic flow signals with feedback signals from MSTd carrying predictions about the expected global motion pattern associated with the observer's self-motion. Sensory signals that match the predicted motion parallax and disparity signals reinforce the self-motion signal in MSTd, and the MT signals that mismatch the feedback from MSTd are suppressed. Because object motion signals naturally deviate from the prediction, MT-MSTd interactions automatically factor out the self-motion component. Hence, world-relative object motion signals emerge as a prediction error. Our model offers a new perspective of how humans perceive world-relative object motion during self-motion and clarifies related problems, such as how observers discern stationary from moving objects.

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33.3017 **Existence of acceleration sensitive units in pre-attentive visual system** Ryohei Nakayama[1], Isamu Motoyoshi[1]; [1]Department of Life Sciences, The University of Tokyo, [2]Department of Life Sciences, The University of Tokyo

It has been believed that human visual system is insensitive to accelerations in moving stimuli. The notion is notably supported by evidence that detection sensitivity for velocity modulation in moving stimuli exhibits low-pass characteristics against temporal frequency of velocity modulation (e.g., Werkhoven et al., 1992). On the other hand, recent studies demonstrate a biphasic temporal response of motion detectors, leading to a notion that the visual system is sensitive to accelerations at some processing levels. To revisit visual sensitivity for accelerations, we here re-examined the velocity modulation sensitivities for a wide range of conditions. Stimulus was a horizontal square-wave grating (0.5 cpd) that drifted at a temporal frequency of 10.7 Hz within a square window (3.2 x 3.2 deg) or within a vertically elongated window (H3.2 x V22.7 deg). For the both window conditions, detection thresholds were measured for sinusoidal velocity modulations of various temporal frequencies (0.25 - 8 Hz). The results showed that the modulation sensitivity function had a low-pass shape for stimuli with a long window, but was a band-pass shape for stimuli with a short window (peak at ~1 Hz). Similar band-pass characteristics were observed for Gabor stimuli. We also found that, even for stimuli with a long window, the low-pass sensitivity curve was altered into band-pass when observer's attention was removed by the concurrent letter identification task. An additional visual-search experiment also revealed that a target dot moving with a velocity modulation at relatively high temporal frequencies (~2 Hz) was the most easily detected among dots moving with various constant velocities. These results support a notion that high sensitivity to sluggish velocity

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modulations is a product of attentive tracking of continually moving stimuli, and that the visual system is primarily sensitive to accelerations and/or decelerations at the pre-attentive level.

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33.3018 Temporal dynamics of perceiving scene-relative object motion during self-motion from optic flow Long NI[1](nilgucas@hotmail.com), LI LI[2,3]; [1]Center of Neural Science, New York University, New York, USA, [2]Neural Science Program, New York University Shanghai, Shanghai, PR China, [3]Department of Psychology, The University of Hong Kong, Pokfulam, Hong Kong SAR

The visual system can recover scene-relative object motion by removing the self-motion component from the object's retinal motion, a process called flow parsing. However, little is known about the temporal dynamics of flow parsing. Here we addressed this question by examining how flow parsing gain (i.e., the proportion of self-motion component subtracted from the object's retinal motion) is modulated by the exposure time to optic flow. A stereo display simulated forward self-motion at 0.30m/s through a cloud of 58 red wireframe objects (depth range: 0.34m) with a yellow dot probe (diameter: 0.0025°) moving vertically in the scene. In the full-field condition, objects appeared on the entire image plane (56°x33°), thus providing both global and local motion information around the probe. In the hemi-field condition, objects were placed on the opposite side of the probe on the image plane, thus removing local motion information around the probe. Five display durations (100ms, 200ms, 400ms, 700ms, & 1000ms) were tested. The midpoint where the probe was visible for each display duration corresponded to the same time point (900ms) in a 1000ms display, ensuring the same depth, eccentricity, and self-motion component of the probe in the cloud. A self-motion component was added to the probe's retinal motion using an adaptive staircase to determine when the probe was perceived to move vertically in the scene. Across 11 participants, the flow parsing gain remained unchanged across the five display durations for the full-field display, but decreased with duration for the hemi-field display, which was not due to the perceived heading bias as revealed by our control experiment. We conclude that both global and local motion affect the temporal dynamics of flow parsing. Flow parsing is a fast process (≤100 ms), and its accuracy appears to decrease with an increased exposure to global flow.

33.3019 Vestibular and visual Information are required for the accurate perception of object motion during self-motion Mingyang Xie[1](coolkid0118@163.com), Diederick Niehorster[2], Markus Lappe[2], Li Li[3,4]; [1]Institute of Cognitive Neuroscience, East China Normal University, Shanghai, PRC, [2]Institute of Psychology, University of Muenster, Muenster, Germany, [3]Department of Psychology, The University of Hong Kong, Pokfulam, Hong Kong SAR, [4]Neural Science Program, NYU Shanghai, Shanghai, PRC

Although humans can accurately perceive scene-relative object motion during self-motion in the real world, recent studies reported that such object motion perception is not accurate when based on visual information alone. Here we extend this work by systematically examining the perception of scene-relative object motion based on vestibular information only, visual information only, and combined vestibular and visual information. In the vestibular only condition, observers wore a Head Mounted Display (Oculus DK2, 100° FOV) and walked at 1 m/s through an empty ground environment that provided no flow information about self-motion. In the visual only condition, observers viewed a simulation of linear translation at the same speed over a random dot ground environment that provided optic flow. In the combined vestibular and visual condition, observers walked through the random dot ground environment. For all three display conditions, a fixation point was placed on the ground in front of the observer. After 1s of self-motion at 1 m/s, this fixation point disappeared and a moving red dot probe (diameter: 1°) appeared in front of the observer at 15° below the horizon. The probe moved sideways in the virtual world at 6°/s, and observers judged whether the probe moved away or toward them using a handheld controller. We found that with only vestibular information about self-motion, about half of the probe's retinal motion component due to self-motion (mean±SE: 54%±4%) was removed for the recovery of scene-relative object motion. With only visual information, a higher percentage (81%±4%, $t(11)=4.830$, $p< 0.05$) was removed. With combined vestibular and visual information, the percentage removed increased to 98%±3% ($t(11)=5.785$, $p< 0.05$). We conclude that neither vestibular information nor visual information alone is sufficient for the accurate perception of scene-relative object motion during self-motion. Accurate perception of scene-relative object motion requires the integration of vestibular and visual information.

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33.3020 The Plasticity of Eye Movements Compensation in Macaque VIP Hu Deng[1,2](dengh@psych.ac.cn), Shengbing Kuang[1], Shengguang Li[1], Tao Zhang[1,2]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences, Beijing 100101, China, [2]University of Chinese Academy of Sciences, Beijing 100049, China

Primate ventral intra-parietal (VIP) area is a key region for judging heading direction, especially when pursuit eye movements are involved. In previous studies, monkeys had been well trained in heading discrimination task before neuronal data collection. Although behavioral training can significantly improve monkeys' performance in heading discrimination task during pursuit eye movements, it still remains unclear whether this behavioral change can be sufficiently supported by the neuronal plasticity in VIP or not. We recorded neuronal responses of macaques' VIP to the same heading stimuli before and during heading discrimination training. Behavioral performance was collected simultaneously during training. Visual stimuli were constructed by simulating monkey moving toward a 3D cloud of points. Heading angle was varied along horizontal line. To evaluate the contributions of retina and extra-retina signals, we included simulated pursuit eye movements condition besides fixation and real pursuit eye movements. We found that the behavioral improvement in training involved real pursuit eye movements couldn't be transferred to the simulated pursuit condition, even their visual inputs were identical. Then, we found that training significantly increased the sensitivity of VIP neurons at all eye movements conditions (Two-way Anova, training main effect, $p< 0.001$). On the other hand, training didn't reduce the separation of heading tuning among different pursuit eye movements conditions, suggesting no additional contribution to solve compensation problem (Two-way Anova, training main effect = n.s.). Our results suggest that the neural system can use visual cues solely to compensate smooth pursuit eye movements, but the strategy is not the same as in real eye movements scenario. Training can gradually increase the VIP neurons' sensitivity at all eye movements conditions, but has no direct contribution in eye movements compensation. Therefore, eye movements compensation might rely on the rapid and flexible change of read-out rule, instead of neural tuning plasticity of sensory system.

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33.3021 Is Serial Dependence Sticky or Predictive? Ye Xia[1](yexia@berkeley.edu), David Whitney[1]; [1]University of California, Berkeley

Serial dependence, an effect in which the perception of a stimulus is biased towards recent percepts, has recently been demonstrated in a wide range of visual features (e.g. orientation, numerosity, facial identity, and attractiveness). This perceptual bias may counteract visual noise and uncertainty in object representations, and is thus believed to be adaptive, since real world objects are often much more stable than their constantly changing image properties. However, in cases where objects being perceived are not stable but undergoing a continuous change, is there a perceptual bias towards the recent past (sticky bias) or towards the expected change (predictive bias)? We studied this question by modifying an experimental paradigm used in previous studies demonstrating serial dependence for the perception of orientation. Subjects were asked to report the orientation of a sequence of arrows by matching a response bar. Instead of changing the orientation of the arrow randomly across trials, we rotated the arrow in a sometimes-predictable-sometimes-unexpected way. In the "predictable" trials (about 75%) the arrow was rotated by 16 degrees in a consistent direction from the previous trial inducing an expected continuous change. In the "unexpected" trials (about 25%, randomly interspersed among the "predictable" trials) the arrow was rotated either clockwise or anti-clockwise by 8 degrees. While a sticky bias would predict a perceptual pull toward the 1-back stimulus for "unexpected" trials, our results showed a percep-

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tual pull towards the expected orientation for those trials, which suggests a contribution of predictive bias. This could not be explained by a simple response bias in the expected direction of rotation because such a response bias was not observed for the "predictable" trials. Our results suggest that serial dependence may also have a predictive component that facilitates the perception of continuous changes when they should be expected.

33.3022 **Temporal derivative of the elevation angle as a cue for visually perceived gravity** Björn Jörges[1](bjoern_joerges@hotmail.de), Joan López-Moliner[1]; [1]Departament de Cognició, Desenvolupament i Psicologia d'Educació (Universitat de Barcelona)

There is evidence that the visual system uses earth gravity (1g = 9.81 m/s²) in a prior-like fashion for different tasks. Relatively soon, we might, however, be exposed visually to gravities other than 1g (f. e. in augmented/virtual reality). With this motivation, we designed an experiment to establish the human ability to distinguish between different visually presented gravities. To this end, we employed a two-interval forced choice paradigm: participants were shown spheres of tennis ball size approaching them on parabolic trajectories. These trajectories were governed by seven different gravities (from 0.7 g to 1.3 g in steps of 0.1 g), two horizontal velocities (6.0 m/s and 8.33 m/s) and two initial vertical velocities (3.7 m/s and 5.2 m/s). Each trial consisted of a pair of parabolas, one of which was governed by earth gravity and the other by one of the seven test gravities. The kinematic values were chosen such that trivial cues like height or presentation time did not by themselves predict the underlying gravity value unequivocally (f. e. the higher parabola was not always the one with lower gravity). Participants were asked to judge which of the two parabolas had the higher underlying gravity. Not all subjects could discriminate different gravities. For those who did perform above chance level, the response pattern was best explained by the temporal derivative of the elevation angle at the top point of the parabola, which depends on the value of gravity. This information may be used in a relative way by combining the rate of change of the elevation angle with the elevation angle itself. We conclude that, while the visual system is principally capable of distinguishing gravities, it does so in an indirect fashion by processing optic flow information dependent on the gravity value.

Motion: Higher order

Sunday, May 21, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

33.3023 **Performed overt actions can disambiguate ambiguous apparent motion** Allison Allen[1](alkallen@ucsc.edu), Nathan Heller[1], Nicolas Davidenko[1]; [1]Psychology Department, UC Santa Cruz

Previous research has shown that ambiguous motion can be resolved in favor of the direction of a performed overt action (e.g., Wohlschäger, 2000). However, these studies have used paradigms in which the motion could only be disambiguated in one of two directions (e.g. clockwise versus counter-clockwise). Recently Davidenko and colleagues (Davidenko et al., VSS 2015, CogSci 2015) reported an illusion in which randomly refreshing pixel textures can elicit percepts of coherent apparent motion, referred to as illusory apparent motion (or IAM). One benefit to using IAM as a paradigm is that the random dots can be perceived as moving in any number of directions. The current study explores whether IAM can be used to study motion disambiguation by overt action. Subjects (n = 17) completed three blocks of trials. The stimuli consisted of a single static frame of random pixels that shifted either left or right by 4 pixels. To manipulate ambiguity, in low-noise trials 10% of pixels were randomly refreshed, versus 30% in medium-noise trials, and 100% in pure-noise trials. In the first two blocks, no action or a single button press was required to begin each trial. In the third block, subjects performed an overt action, pressing a left arrow, a right arrow, or an X (to indicate random/other) to begin each trial. After each trial, subjects reported the motion they saw by pressing a left or right arrow or an X. Our results indicate that during 10%-noise trials, subjects were no more likely to report motion consistent with their overt action than would be expected by chance (M = 31.6%, SE = 1.8%), whereas during 30%-noise trials this was significantly more likely (M = 39%, SE = 2.5%; t(16) = 240, p = .029). Our findings suggest that IAM is susceptible to disambiguation by performed overt actions.

33.3024 **Attention modulates the motion aftereffect: A meta-analysis.** Laura Bartlett[1](lb1g13@soton.ac.uk), Nicholas Hedger[1], Erich Graf[1], Wendy Adams[1]; [1]Psychology, University of Southampton

Many studies suggest that the motion aftereffect (MAE) is modulated by attention: MAEs are reduced if attention is diverted from the adaptation stimulus by a demanding task at fixation (e.g. Chaudhuri, 1990; Taya et al., 2009). However, a series of null findings (Morgan, 2011, 2012, 2013) suggest that previous reports of attentional modulation may be due to response bias. Nonetheless, we previously found attentional modulation in a paradigm designed to eliminate response bias (Bartlett, Adams & Graf, 2016). To better understand the conditions under which attention modulates the MAE, we conducted a meta-analysis of the behavioural literature that included 98 effect sizes across 42 independent samples. Overall, attention significantly and substantially modulated the MAE; this was a very large effect (Cohen's d=0.99, p< .001). Various characteristics of the adaptation and test stimuli affected this modulation: Significantly larger attentional effects were found for (i) simple (translational) motion vs. complex motion, (ii) dynamic vs. static test stimuli, (iii) greater eccentricity (minimum distance from fixation) and (iv) smaller maximum diameter. Are reported effects of attention inflated by response bias? Bias should be minimised in studies that (i) used naïve observers, (ii) measured the magnitude (vs. duration) of the MAE, and (iii) employed 2AFC tasks. However, none of these factors significantly modulated the effect. In fact, there was a trend for studies with only naïve observers to report larger effects. It is unlikely, therefore, that response bias plays a substantial role in reported effects of attention. The effect of attention on the MAE is large and best explained by a multiple moderator model that includes (i) motion type (simple vs. complex), (ii) stimulus eccentricity, (iii) stimulus maximum diameter and (iv) subject naivety. This model included 39 effect sizes (the subset for which all moderators were reported) and accounted for 49% of variance in effect size.

33.3025 **Vertical anisotropy in stream/bounce perception of refracted motion trajectory** Akihiko Gobara[1,3](ackey0299@gmail.com), Yuki Yamada[2]; [1]Graduate School of Environmental Studies, Kyushu University, [2]Faculty of Arts and Science, Kyushu University, [3]Japan Society for the Promotion of Science

When two identical objects moving toward each other coincide at the center and then pass through, observer perceives either of two motion events: streaming or bouncing (stream/bounce perception). In this study, we examined whether motion direction and trajectory refraction at the coincidence affect the stream/bounce perception. In Experiment 1, two identical black circles moved downward from the upper visual field (downward condition) or upward from the lower visual field (upward condition) at an angle of 45°. They coincided at the center of the display, and then their motion trajectory refracted up or down in the range of 0° to 15°. The velocity of the moving object was 6.21°/s. The results showed that a bouncing rate was significantly higher in the upward condition than in the downward condition, and significantly higher in the up 12° and 15° refraction conditions than in the 0° (i.e., no refraction) condition. In Experiment 2, we investigated the effect of the stimulus velocity on this phenomenon by manipulating the velocity to 2.07°/s (slow condition) or 10.35°/s (fast condition). The results indicated that the fast condition elicited a significantly higher bouncing rate than the slow condition although the effects of the direction and refraction on stream/bounce perception were not varied by the velocity of moving objects. In Experiment 3, we manipulated the duration of post-coincidence motion within the range of 150 ms to 600 ms. The results again showed the similar effect regardless of the post-coincidence duration, indicating that relatively short trailing motion is sufficient for this phenomenon. These results suggest that the mechanisms to detect motion information of vertical direction, refraction after coincidence, and velocity of moving objects underlie the stream/bounce perception maybe independently.

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33.3026 **It's not all black and white: Visual speed perception depends on local, structural and global scene features** Céline Gravot[1,2,3], Alexander Knorr[4], Stefan Glasauer[2,3,4], Hans Straka[1,2,3]; [1]Division of Neurobiology, Department Biology II, Ludwig-Maximilians-Universität München, [2]Graduate School of Systemic Neurosciences, Department Biology II Neurobiology, Ludwig-Maximilians-Universität München, [3]RTG

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To orient within a visually dynamic environment, animals need to accurately estimate the speeds of objects in their visual field and their own movement through space. The visual features of the environment, however, are subject to large variations: they can differ e.g. in contrast intensity, structure of contours or overall brightness. These properties can be categorized into local, structural and global features. Here, we investigated how these characteristics influence speed perception in an amphibian species (Xenopus laevis) in comparison to human subjects. The optokinetic reflex (OKR) is a gaze-stabilizing motor behavior driven by an internal estimate of the visual surround's movement. Using eye tracking we recorded a behavioral correlate of visual speed estimation signals in semi-intact preparations of Xenopus tadpoles at the level of the brainstem. In a virtual reality setup, moving random-dot visual scenes with different contrast magnitudes (local), signs of contrast (structural) and overall brightness (global) were presented. The obtained results revealed a large difference in OKR amplitude between textures with identical contrast magnitude but inversed sign of contrast by a factor of 2.24±1.01, with a higher sensitivity for white dots on a black background. In addition, we found that the sign of contrast differentially influences speed perception depending on overall brightness. In sets of psychophysical experiments, human subjects were asked to compare the speed of two moving random-dot scenes that differed in sign of contrast and overall brightness. Although there was evidence for an individual bias with respect to the sign of contrast ($\tau_{Kendall}=0.64$, $p< 0.01$), overall no systematic bias with respect to either sign of contrast or overall brightness was detected. Our findings show that brainstem-level processing (Xenopus OKR) appears to be strongly influenced by manipulations of the visual scene, whereas subjective perception (in humans) is robust to a large range of visual features.

33.3027 Transformational Apparent Motion is Driven by Figural Parsing, Not Low-Level Motion Signals

Kevin Hartstein[1](kevin.c.hartstein.gr@dartmouth.edu), Peter Tse[1]; [1]Psychological & Brain Sciences, Dartmouth College

High-level figural processing constrains the interpretation of ambiguous motion under certain conditions (Tse, Cavanagh, & Nakayama, 1998). Transformational Apparent Motion (TAM) occurs when one figure is replaced by another that overlaps its location, causing observers to perceive a shape change of the original object. TAM occurs whether objects are defined by luminance (first-order TAM) or texture (second-order TAM; Hartstein & Tse, VSS 2016). Although the previous experiment found a weaker effect for texture-defined objects, we found no difference in the strength of the illusion between first and second-order TAM when using a dynamic white noise background, indicating strong dependence on high-level figural processing rather than low-level motion energy. While fixating a central point (monitored by an eyetracker), two horizontally or vertically aligned squares were presented to observers. At variable stimulus onset asynchronies, a rectangle appeared connecting the squares. Concurrently, a cue-square appeared adjacent to one of the original stimuli, biasing the direction of perceived motion toward that side (as in Tse, 2006). Stimuli were black on a gray background (first-order TAM) or static white noise on a dynamic white noise background (second-order TAM). The dynamic white noise background allowed shape information to persist between the appearance of the initial stimuli and the rectangle that produced motion perception. Participants indicated whether they perceived motion and in what direction. A compelling TAM illusion was perceived in both conditions, with no difference between first and second-order displays. TAM suggests a figural processing and matching step in the high-level motion pathway that precedes perception of motion. The current result suggests that this figural parsing is sufficient to produce an equally strong illusion without first-order motion signals. Further research explores whether endogenous attention alone is sufficient to provide the figural parsing information necessary for TAM without exogenous cues.

33.3028 The effect of stimulus area on global motion thresholds in children and adults

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Introduction: Coherence thresholds on a global motion task vary as a function of spatial and temporal stimulus parameters. This is of particular interest when studying visual development, because these parameters can have a larger impact on the performance of young children compared to adults. For example, children perform better when presented with a denser dot array while adult performance is unaffected (Narasimhan & Giaschi, 2012). We have shown that coherence thresholds for global motion direction discrimination are immature in 4-6 year olds when smaller spatial displacement (Δx) values are used to create stimulus motion, but adult-like when larger values are used (Meier & Giaschi, 2014). The current study was designed to investigate whether the apparent immaturity in motion perception for small displacements is due to immaturity in spatial integration mechanisms. To this end, we assessed the effect of stimulus area on global motion coherence thresholds in young children. Methods: Coherence thresholds were assessed in children (4.5 – 6.5 years, M = 5.5) and adults (18.6 – 29.9 years, M = 21.3) using a two-alternative forced choice direction discrimination task with a staircase paradigm. Nine conditions were assessed: spatial displacement was 1, 5, or 30 arcmin; stimulus area was 9, 36, or 82 deg2. Participants were assessed monocularly, and conducted one staircase per condition, for a total of 9 measurements. For each participant, we calculated the change in coherence threshold as a function of stimulus area at each spatial displacement. Results: There was a significant effect of spatial displacement, such that an increase in coherence threshold with decreasing area was present for large displacements (Δx = 30 arcmin) only. There was no effect of age group, and no age group by displacement interaction. Conclusion: Immaturities in global motion perception are unlikely to be accounted for by limitations in spatial integration area.

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33.3029 The Reference Frame for Encoding and Retention of Motion-Direction Information Depends on Stimulus Set-size

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We investigated the reference frames used in perceptual encoding and storage of motion-direction information. Observers (N=4) viewed multiple moving objects while (1) maintaining gaze on a fixation point (Experiments 1a-1b); or (2) performing smooth-pursuit eye-movement (Experiments 2a-2b). Their task was to report the direction of motion of a randomly selected object by adjusting the orientation of a bar. To characterize the initial encoding stage, in Experiments 1a and 2a the target to be reported was cued immediately after objects stopped moving and disappeared. Experiments 1b and 2b included varying cue delays to tap into sensory memory and VSTM. Using a vector-decomposition technique, we computed performance during smooth pursuit with respect to a spatiotopic (non-retinotopic) and a retinotopic component and compared them with performance during fixation, which served as the baseline. For the stimulus encoding stage, we found that the reference frame depends on the stimulus set-size. For a single moving target, the spatiotopic reference frame had the most significant contribution with some additional contribution from the retinotopic reference frame. When the number of objects increased (set sizes 3 to 7), the spatiotopic reference frame alone was able to account for performance. Finally, when set size exceeded 7, the distinction between reference frames vanished. We interpret this finding as a switch to a more abstract, non-metrical encoding of motion direction. Results with non-zero cue delays indicated that the retinotopic reference frame was not used in memory. Our results suggest that, whereas a retinotopic reference frame may be employed for controlling eye-movements, reference frames used in perception and memory are primarily non-retinotopic. Furthermore, the use of non-retinotopic reference frames appears to be capacity limited. In the case of complex stimuli, the visual system may use perceptual grouping to reduce complexity or resort to an abstract, non-metrical coding of motion information.

33.3030 **Assessment of mid-level vision segregation in mice with radially expanding/contracting targets** William John Redmond[1](williamjohn.redmond@kuleuven.be), Christophe Bossens[1], Hans Op de Beeck[1]; [1]Laboratory of Biological Psychology, Department of Psychology, KU Leuven

Rodents' ability to segregate and recognize objects is still debated today. Our group showed that rats can distinguish figures on a background by focusing on luminance-based first-order cues. In a follow-up study, we demonstrated that rats can then learn to differentiate between figures defined by second-order texture-based cues. The aim of this current study was to design and test a novel discrimination task for mice to test whether they can differentiate between complex motion trajectories based upon second-order cues. 8 mice separated in two groups performed discrimination tasks in automated touch screen operant chambers for 28 testing days. Group 1 had an expanding white square on a black background as a target, group 2 a contracting one (Phase 1), which were then showed simultaneously during testing on the two touchscreens. In a second phase, both black and white squares on inverted backgrounds were randomly interleaved (Phase 2). For Phase 1, 3 out of the 4 mice in the contracting group reached threshold performance of 75% correct after 18.8±5.0 sessions. Interestingly, only 1 out of the 4 mice in the expanding group reached threshold level in 28 sessions. Of interest, mice in the expanding group were thrice as likely to fail to perform 30 trials per session (31.3±3.7% vs 9.8±5.5% of the time). This suggests a possible selection bias toward contracting targets, which will be further evaluated. The mice that passed threshold in step 1 had an average discrimination score of 82.8±4.6% during their first session when introduced to Step 2, indicating that they can generalize. Their score then all slightly dropped, before reaching back threshold in about 4 sessions. Our data indicate that mice can distinguish complex motion trajectories while ignoring luminance-based cues. Radially expanding/contracting targets are thus an interesting tool for probing figure-ground segregation capabilities of rodents.

Acknowledgement: Human Brain Project

33.3031 **Volitionally altering the immediate past: Postdictive Biasing of Perceived Motion Direction** Liwei Sun[1](liwei.sun.gr@dartmouth.edu), Kevin Hartstein[1], Sebastian Frank[1], Peter Tse[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College

Among physical events, it is impossible that an event could alter its own past for the simple reason that past events cause future events and not vice versa. To do so would amount to impossible self-causation. However, mental events are constructed by processes that take a finite duration. It is therefore conceivable that later events could alter the ongoing interpretation of previous events if they arrive within this finite duration and before a commitment has been made to what must have happened in the world to generate the image sequence. In the current study, we showed that humans can volitionally bias how they will perceive an ambiguous apparent motion sequence, as long as the top-down auditory command occurs within ~133 ms after the occurrence of the actual motion event in the world. This finding supports the idea that there is a temporal integration period during which perception is constructed on the basis of both bottom-up and top-down inputs.

33.3032 **The effects of local and global noise on confidence judgments** Alan LEE[1](alanlee.lingnan@gmail.com); [1]Department of Applied Psychology, Lingnan University, Hong Kong

Confidence judgment involves subjective evaluation of uncertainty in performing a task. For a task that requires the visual system to integrate multiple elements in the stimulus, there are two sources of uncertainty: Noise pertaining to local, individual elements affects lower levels of processing, while variability across elements affects the global integration of elements at higher levels of processing. How does noise at different processing levels affect confidence judgments? The present study addresses this question using a local-global-noise paradigm. The stimulus was a multiple-aperture motion pattern, consisting of an array of randomly-oriented, drifting-Gabor elements, superimposed with dynamic pixel noise. Global signal-to-noise ratio (GSNR) was defined as the ratio between the coherently-moving (signal) elements and randomly-moving (noise) elements. Local signal-to-noise ratio (LSNR) was defined by the contrast ratio between Gabor and noise pixels. In each trial, observer judged the global rotational direction (clockwise or counterclockwise), and simultaneously gave a confidence rating (high or low) on the direction judgment. Four levels of LSNR were fixed for each observer based on a prior calibration session. At each LSNR level, GSNR threshold was varied using an adaptive-staircase procedure, so that direction-judgment accuracy converged to 75%. For a constant direction-judgment accuracy, a tradeoff between local and global noise was found, suggesting that perceptual sensitivity can be equated between a low-LSNR-high-GSNR stimulus and a high-LSNR-low-GSNR stimulus. Analysis on confidence judgments was based on the signal-detection theoretic approach (Maniscalco & Lau, 2012). No systematic difference in meta-d' was found between low-LSNR-high-GSNR and high-LSNR-low-GSNR stimuli. However, confidence criterion tended to be more liberal for high-LSNR-low-GSNR stimuli than for low-LSNR-high-GSNR stimuli, suggesting that observers tended to be more confident when global uncertainty was high than when local uncertainty was high, despite similar first-order performance. These findings suggest the level at which uncertainty exists affects the confidence criterion, but not metacognitive sensitivity.

DEVELOPMENT: TYPICAL AND LIFESPAN

Sunday, May 21, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

33.3033 **A Comparison of Electrophysiological and Behavioral Measures of Visual Acuity** Nakita Ryan[1](nmeagan@mun.ca), Gabrielle Hodder[1], Lauren King[1], James Drover[1]; [1]Psychology, Memorial University of NL

Unlike behavioral techniques, the measurement of visual evoked potentials (VEPs) provides an objective electrophysiological measure of vision directly from the visual cortex. The purpose of the present study is to provide the first comparison of visual acuity scores obtained using a new VEP system and those obtained using behavioral tests. Grating acuity was estimated in 27 participants (M = 21.2±1.5 years) using the VeriSci Neucodia VEP system following the sweep VEP (sVEP) procedure. During each 10 second sweep, participants were presented with 8 horizontal square wave gratings ranging from 5.3 to 35.6 cpd (0.75 to -0.07 logMAR). Each participant completed 8 sweeps. Grating acuity was also measured using the Teller Acuity Cards II (TAC) and optotype acuity was estimated using the Early Treatment Diabetic Retinopathy Study (ETDRS) visual acuity test. Scores from the three tests were compared. In addition, coefficients of repeatability (COR) were determined for all possible test pairs in order to determine level of agreement. Friedman analyses revealed a significant test effect ($p< 0.0001$). Specifically, ETDRS scores were significantly finer than scores obtained with sVEP (-0.04 v. 0.12 logMAR, $p< 0.0001$) and the TAC (-0.04 v. 0.11 logMAR, $p< 0.0001$). TAC and sVEP scores did not differ (TAC=0.11 logMAR; VEP=0.12 logMAR; $p=0.52$). COR analyses indicated that the level of agreement between all test pairs was poor and virtually identical (TAC and sVEP COR=0.30 logMAR; sVEP and ETDRS COR=0.30 logMAR; TAC and ETDRS COR=0.31 logMAR). The poor agreement between tests is not surprising given that they assess different visual abilities (i.e., TAC and sVEP: resolution acuity; ETDRS: recognition acuity). Furthermore, the tests likely tap different underlying neural mechanisms as VEPs are recorded directly from the visual cortex, whereas the TAC and the ETDRS require a behavioural response and therefore, likely tap mechanisms further upstream within the visual system and beyond.

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33.3034 **A Comparison of the Developmental Rates of Three Visual Functions** Shelley Cornick[1](scornick@mun.ca), Darcy Hallett[1], Jacqueline Higgins[1], James Drover[1]; [1]Department of Psychology, Memorial University of Newfoundland

A comparison of the developmental rates of different visual functions can offer a clearer understanding of the visual system and reveal whether these functions are mediated by the same or different underlying neural/optical components. In the present study, 255 children (range: 2.7 to 12.4 years) were tested monocularly on grating acuity, vernier acuity, and contrast sensitivity (CS) using similar card-based tests. Grating acuity was measured using the Teller Acuity Cards II. Vernier acuity was measured using the vernier acuity cards. CS was measured at 0.75, 3.0, and 12.0 cpd using CS cards created by our laboratory. Pearson correlation coefficients were

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calculated to determine the relationship between each dependent measure and age. The strength of each correlation coefficients was taken as an index of developmental rate. The correlation coefficients were compared to determine whether there were significant differences in developmental rates. Vernier acuity demonstrated the most rapid developmental rate (r=-0.64), followed in order by CS at 12 cpd (r=0.58), grating acuity (r=0.55), CS at 0.75 cpd (r=0.44), and CS at 3.0 cpd (r=0.33). However, the rate of vernier acuity development was not significantly faster than that of CS at 12 cpd or grating acuity (both p>.05). Both vernier acuity and CS at 12 cpd demonstrated significantly faster developmental rates than CS at 3 and 0.75 cpd (both p< .05). The results also indicate that vernier acuity surpasses grating acuity and becomes a hyperacuity between 3 and 4 years of age. The finding that the developmental rates of vernier acuity and grating acuity did not differ was surprising as they are speculated to be mediated by different underlying components (grating acuity: retina; vernier acuity: visual cortex). Also, the faster developmental rate of CS at 12 cpd compared to 3 and 0.75 cpd may reflect the existence of different underlying spatial frequency channels.

33.3035 Differences in Transitional Saccades in 4-month-olds When Viewing Pairs of Possible and Impossible Objects

Julie Planke[1](plankej1@hawkmail.newpaltz.edu), Sarah Shuwairi[1]; [1]State University of New York at New Paltz

Previous work demonstrated that 4-month-olds responded with longer looking and increased oculomotor activity toward pictures of impossible cubes relative to possible ones, suggesting infants are able to selectively respond to vertex information that is diagnostic of structural coherence. However, it left open the question of whether 4-month-olds would systematically respond with increased visual interest to other geometrically impossible figures. We tested 4-month-old infants in an eye-tracking paradigm with novel pairs of possible and impossible objects (e.g., ovals, rectangles). We hypothesized that infants would engage in active comparison of the objects and that impossible figures would evoke increased selective looking in order to resolve the global structural anomaly. Infants again fixated longer on the impossible cube relative to the possible one (p < .05), and produced a greater number of transitional saccades between the interior critical region and neighboring regions of the impossible relative to the possible cube (p < .01). Although dwell times for the other possible-impossible mates did not differ reliably, there were significantly more transitional shifts of gaze between the upper and lower halves of the ovals (p < .01) and inner and outer regions of the rectangles (p < .05) as a function of possibility. The effect of greater visual interest for impossible shapes did not generalize across all shape pairs. Infants apparently more actively examine some impossible figures, although there is a large amount of variability in infants' fixation behaviors. This may be due to individual differences in selective looking or emerging sensitivity to pictorial depth information, or it may be a stimulus-dependent response that manifests exclusively with certain shapes (e.g., salient manipulations of T-junctions). These findings suggest that some mechanisms for registering pictorial depth and representing 3D object coherence are available early and continue to develop rapidly within the first several months.

33.3036 Dynamic Characteristics of 5 to 22 week-old Infants' Accommodation and Vergence Tracking Responses

Colin Downey[1](colodown@indiana.edu), Griffin Pace[1], Eric Seemiller[1], Rowan Candy[1], Larry Cormack[2]; [1]Indiana University - Bloomington, [2]University of Texas

The motor and sensory binocular visual systems develop dramatically during the first 5 months after birth. Typical development of stereopsis is dependent on adequate image quality and alignment in the dynamic natural environment, requiring appropriate accommodation (A) and vergence (V). This study documented the development of dynamic characteristics of infant accommodation and vergence responses between 5 and 22 weeks of age, using a correlogram approach (Mulligan et al, 2013). Fifteen infants (two excluded due to restlessness) and 10 adult controls were tested during trials in which they viewed naturalistic cartoons presented on a screen. The stimulus moved as a random walk in depth between 33-80cm for 100 seconds. Horizontal eye position and refractive state were recorded binocularly and simultaneously at 50Hz using eccentric photorefraction and Purkinje-image eye-tracking analyses of video images (PowerRef 3, PlusOptix). Cross-correlations of the stimulus and response velocities demonstrated steady maturation of (V) and (A) between 5 and 22 weeks. Adults demonstrated mean peak correlations of 0.80±0.03 for (V) and 0.75±0.10for (A, left eye), at mean time lags of 0.15s±0.04 (V) and 0.20±0.05 (A,left). 5-9 week-olds, 10-13 week-olds and >14 week-olds had mean peak correlations of 0.54±0.17, 0.67±0.11 and 0.60 ± 0.15 (V) and 0.52±0.16, 0.61±0.12, 0.52±0.14 (A,left), at time lags of 0.42s±0.20, 0.25s±0.07, 0.26s±0.11 (V) and 0.36s±0.12, 0.23s±0.07, 0.28s±0.13 (A, left). These data indicate that by five weeks of age, some infants are able to track these unpredictable dynamic stimuli with short delays on the order of only 0.3s (V) and 0.2s (A, left) slower than adults, albeit with more response variability as indicated by reduced peak correlations.

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33.3037 Vergence responses to changing disparity in 5 to 10 week old human infants.

Eric Seemiller[1](eric.seemiller@gmail.com), T. Candy[1]; [1]Indiana University School of Optometry

Numerous studies have suggested that young infants do not respond to binocular cues such as retinal disparity until approximately 3 to 5 months of age (e.g., Petrig et. al, 1981; Thorn et. al, 1994). However, full-cue vergence responses have been observed in newborns (Slater and Findlay, 1975) and examined quantitatively in 2-month-olds, who responded to a 2 deg. stimulus in depth (Seemiller et. al, 2016). In adults, small errors in vergence responses are corrected using the disparity cue. Is it possible that vergence responses can be driven by disparity at younger ages than the classically documented onset of disparity sensitivity? 22 full-term, typically developing infants were tested between 5 and 10 weeks postpartum. Subjects viewed a large field (44 x 66 deg.) dynamic random noise stimulus that oscillated in disparity sinusoidally (0.1 Hz, amplitude = 2 degrees) for 30 seconds. Horizontal eye position was measured using a Purkinje image eye tracker (PlusOptix) at 50 Hz. Fast Fourier Transforms were then used to compare the amplitude of their vergence response at the frequency of the stimulus to an estimate of background vergence noise. Usable data were collected from 16 of 22 infants (mean age = 56.2 +/- 10.0 days) and 10 adult controls. Across the group, responses at the frequency of the stimulus were significantly larger than at the adjacent frequencies for both infants (paired t-test: t = 6.374, p < 0.00001) and adults (t = 10.602, p < 0.000001). These results suggest that infants in this age group are capable of processing disparity at a younger age than previously believed; responses were observed in the youngest infants tested (35 days). Furthermore, because the noise fields were temporally uncorrelated, there was no static feature for independent monocular alignment or "bifoveal fixation" (e.g., Held, 1993).

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33.3038 Exploring the neural foundation of scene recognition development from middle childhood to adulthood

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Navigating our environment is of high ecological relevance for humans and involves processing of the visual scenery. Scene processing, however, develops with age: Behavioral studies show that visual scene processing improves before and beyond the age of 6 and reaches adult levels at 10 years only. But what is the neural foundation for this development? Scene processing relies on a network of functionally scene-selective areas comprising the parahippocampal place area (PPA), retrosplenial complex (RSC) and transverse occipital sulcus (TOS) in adults. However, the driving neurocognitive factors for the behavioral development of scene processing remain unclear and are therefore targeted here. Using an fMRI localizer for scenes vs objects in three age groups, we investigated the development of scene recognition's neural foundation. So far, we functionally defined scene-selective ROIs (PPA, RSC, TOS) in adults (child-ROIs will follow). Then, we analyzed BOLD amplitudes within each ROI with regard to stimulus category (scenes, objects) as within-subject factor and age group (7-8, 11-12, 19-23 years) as between-subject factor conducting repeated measures ANOVAs. Preliminary analysis on data of six 7-8-year-olds, four 11-12-year-olds and ten adults revealed significant age group x category interactions in the rTOS, lTOS and rPPA. In these regions, the BOLD amplitudes for scenes did not change with age, while BOLD amplitudes for objects decreased from childhood to adulthood. These results speak in favor of a pruning-back-mechanism for cortical representations of objects – and possibly other non-scene stimulus categories – in scene-selective areas

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over development. Thus, a higher scene-selectivity in adulthood emerges by decreasing the answer to nonpreferred (non-scene) stimuli rather than increasing the answer to preferred (scene) stimuli during childhood. Our results add to the growing evidence that pruning-back cortical representations of nonpreferred stimuli may be one of the key mechanisms in the development of category-specialization in the human brain.

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33.3039 **Development of sensitivity to naturalistic textures in macaque: psychophysics and physiology** Najib Majaj[1](najib.majaj@nyu.edu), Darren Seibert[2], J. Movshon[1], Lynne Kiorpes[1]; [1]Center for Neural Science, New York University, [2]Department of Brain and Cognitive Sciences and McGovern Institute for Brain Research, Massachusetts Institute of Technology

There is ample behavioral evidence that different aspects of visual function develop over different time courses. Furthermore, there is evidence that higher form vision – represented by tasks like figure-ground segmentation and contour integration – matures later than acuity and contrast sensitivity. What remains unclear is how different developmental time courses relate to changes in neural representations. Part of the difficulty is due to the absence of a clear and concise map that links different visual functions to specific visual brain areas or neural substrates. We capitalized on recent findings that linked the processing of higher-order statistics of naturalistic texture images to neural responses in area V2 and sought to characterize the behavioral and neural developmental time course of naturalistic texture sensitivity in non-human primates. We constructed synthetic texture patterns with variable amounts of higher-order statistical structure of original natural images. We studied behavioral sensitivity and neuronal selectivity in macaques ranging in age from 26 to 172 wk. We tested five animals, one of which contributed both behavioral and neural data. We measured sensitivity to naturalistic structure using a 2AFC discrimination task. We measured neuronal responses to the same textures with multielectrode "Utah" arrays targeting the foveal representation of V2 in three awake, head free, fixating macaques. Our results show increased behavioral sensitivity to naturalistic statistics from the youngest to the oldest animals. We found texture selective neuronal responses at all ages, but the mean population texture selectivity increased with age. Lower selectivity in the younger animals was associated with weaker neural activity and longer visual and texture-selective response latencies. These results suggest that sensitivity to natural image statistics improves with age, and that this improvement may be associated with changes in visual processing in V2.

33.3040 **A not-so-narrow spotlight: Infants can encode information about objects into VSTM that were not fixated** Zsuzsa Kaldy[1](zsuzsa.kaldy@umb.edu), Sangya Dhungana[1], Erik Blaser[1]; [1]Department of Psychology, UMass Boston

Background: While the early development of attentional orienting is well described, basic questions related to infants' attentional windows have not been explicitly investigated. Here we measure whether infants can encode information about objects that they did not fixate into their visual short-term memory (VSTM). Methods: Twenty-five 6-month-old infants (age range: 5;0-7;5, 10 females) participated in a free-viewing eye-tracking study. In each trial, infants were presented with a set of identically shaped, but differently colored items spaced symmetrically around central fixation (set size was varied between participants: 4 or 6). After a 1,000 ms exposure, a randomly chosen pair of neighboring items disappeared. Following a 500 ms delay, the two items reappeared for 2,000 ms, with one changed to a new color (target) and the other unchanged (foil). The sudden offset of the two items was the partial report post-cue, designed to trigger coding from iconic memory into more durable VSTM (Blaser & Kaldy, 2010, Psych Sci). We contrasted infants' performance (preference for the target) on trials where, during the initial exposure, they fixated the items that subsequently became the target and foil ('focal look'), versus trials where they did not ('peripheral look'). Results: Infants' overall (collapsed across set size) performance (59.2 ± 11.7% correct), and performance in 'focal look' trials, (62.9 ± 19.1%) were both significantly above chance ($t24=3.93$, $p< 0.0006$, $d=0.78$; $t18=2.95$, $p< 0.008$, $d=0.68$, respectively). In 'peripheral look' trials, performance was 57.1 ± 17.0%, and importantly, also significantly above chance ($t24=2.09$, $p< 0.048$, $d=0.42$). Conclusion: Infants were able to encode and use information about objects that they did not fixate in a change detection paradigm. To our knowledge, this study is the first to show that infants can extract useful information beyond their target of fixation.

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33.3041 **The origins of visual working memory capacity in infants: Implications for theory building** Bret Eschman[1](beschma1@vols.utk.edu), Shannon Ross-Sheehy[1]; [1]University of Tennessee, Knoxville

Visual short-term memory (STM) assessments in infancy can offer important insights into adult models of working memory (WM). Previous work has demonstrated rapid improvements in change detection during the first year of life (e.g., Ross-Sheehy, Oakes & Luck, 2003; Oakes, Ross-Sheehy & Luck, 2006), but classic infant testing procedures make it difficult to determine if we are tapping the same cognitive process in infant tasks that we do in adult WM tasks (e.g., Luck & Vogel, 1997). Thus, the goal of this project was to develop a single change detection task that could be used from infancy through adulthood, so that we may begin to understand the origins of individual differences in adult VWM capacity. Infants (5-, 8-, and 11-mos) and adults completed the task (Fig.1A). Look durations to each circle were calculated, and change preference (minus chance) scores revealed significant effects. There was a significant preference for the changing item at ss2 for 5, 8, 11-mo-olds, and adults (p=.002,.001,.027,.001 respectively), ss3 for 11-mo-olds and adults (p=.054m, & .001, respectively) and ss4 for adults (p=.001). Additionally, changes in pupil dilation during the 3000ms test array revealed a significant effect of change status, $F(1,135)=7.26$, $p=.008$, suggesting pupil dilation may reflect processing associated with memory maintenance and/or change detection. Moreover, pupil change from baseline varied with set size, with smaller sets producing greater dilation. This effect was reversed in adults, suggesting this change from baseline might reflect mental effort associated with successful WM maintenance (see Fig.1B). Taken together, results from this task support and extend previous infant findings, and provide the first data collected using the same task in infants and adults. Our findings suggest that change detection in infancy may reflect the development of adult VWM mechanisms, and provide a means for critical early assessment of theoretical accounts of capacity.

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33.3042 **Reduced inter-hemispheric interference in ageing: Evidence from a divided field Stroop-like paradigm** Julie Castronovo[1](j.castronovo@hull.ac.uk), Jean-Francois Delvenne[2]; [1]University of Hull, [2]University of Leeds

One of the most important structural changes that occur in the brain during the course of life relates to the corpus callosum, the largest neural pathway that connects the two cerebral hemispheres. Whether the corpus callosum has an inhibitory or excitatory function in interhemispheric connection is still debated in the literature. It has been shown that the corpus callosum, and in particular its anterior sections, endures a process of degeneration in ageing. Hence, a primary question is whether such structural changes in the brain of older adults have functional consequences on inter-hemispheric communication. To investigate this question, we asked healthy older adults to perform a modified version of the classic Stroop paradigm in which the target and distracter were spatially separated. Across two experiments, we found that the Stroop effect was significantly reduced when the two stimuli were distributed in two different hemifields as opposed to the same single hemifield. This new finding suggests that age-related callosal thinning reduces inter-hemispheric interference by facilitating the two hemispheres to process information in parallel. The reduced inter-hemispheric interference found in older adults provides strong direct support for the excitatory theory of the corpus callosum.

33.3043 **Motivational effects on reaching adaptation in young and senior adults** Jing Huang[1], Sabine Margolf-Hackl[1], Mathias Hegele[2], Jutta Billino[1]; [1]Department of General Psychology, Justus-Liebig-University Giessen, Giessen, Germany, [2]Department of Sport Science, Justus-Liebig-University Giessen, Giessen, Germany

Previous studies have provided consistent evidence that adaptation to visuomotor rotations during reaching declines with age. Since it has been recently shown that learning and retention components of motor adaptation are differentially modulated by reward and punishment, we were interested in whether age-related decline in reaching adaptation is modulated by motivational feedback. We studied 19 young (M=26.3 years, range 22–36 years) and 18 senior (M=68.2 years, range 60–76 years) adults in a reaching task, which required fast shooting movements towards visual targets with their right hand. Targets and visual feedback of hand position were presented on a mirror which prevented direct vision of the hand. A robotic manipulandum allowed measuring hand position. After a baseline with veridical visual feedback we introduced a 30° counterclockwise visuomotor rotation. After this adaptation phase we also measured retention of adaptation without visual feedback. Participants were randomly assigned to one of three value conditions in which performance was coupled to neutral feedback, monetary gain, or monetary loss. Corroborating previous results, senior adults showed a slower learning rate and a lower overall magnitude of adaptation than young adults (learning rate 0.06 vs. 0.20; directional change 17.9° vs. 26.0°). Retention, however, was found to be similar in both age groups. Motivational feedback had highly age-specific effects. Whereas in young adults adaptation was not modulated by value condition, magnitude of adaptation was larger in senior adults for reward and punishment conditions (directional change: 14.6° neutral, 20.8° reward, 18.5° punishment). Retention was affected by value condition in neither age group. Our results support that in particular senior adults benefit from motivational feedback during reaching adaptation and that age-related decline in visuomotor plasticity can be attenuated by providing value information.

Acknowledgement: German Research Foundation, SFB/TRR 135 Cardinal Mechanisms of Perception

33.3044 Quantifying Changes in Sensitivity to Face Information with Healthy Ageing

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Faces contain a wealth of information which is important for social functioning. Reports suggest that the ability to discriminate one face from another is significantly poorer in older, relative to younger, adults. We aimed to quantify changes in the profile of various aspects of face perception in healthy ageing. Synthetic face discrimination thresholds were measured using a memory-free "odd-one-out" task (Logan et al. 2016). Participants were healthy adults with corrected-to-normal vision (binocular LogMAR VA +0.1 or better). Five age groups (N=10) were tested: 20s (M=20.9±0.8 years), 50-59 (53.7±2.3), 60-69 (64.1±3.9), 70-79 (75.4±2.7) and 80-89 (84.2±3.1). Thresholds were measured for full-faces (upright and inverted), isolated external features (head-shape, hairline), internal features (eyes, nose, mouth, eyebrows) and circular-shapes (control task). Full-face discrimination thresholds increased monotonically as a function of age. Relative to 20-year-olds, thresholds were 1.03X (50-59), 1.10X (60-69), 1.29X (70-79) and 1.40X (80-89) higher in older adults. The effect of ageing in 50-90 year olds was well captured by a linear function: sensitivity declined, on average, by 11% per decade after 50 years. Testing isolated face information showed a similar monotonic decline, however, the slope depended on features: internal feature sensitivity decline was 3.31X and 3.94X steeper than for full-faces and external features respectively. In contrast, the inversion effect did not vary between age groups. Sensitivity to full-faces and component features showed a continuous decline with ageing. While ageing reduced sensitivity to all features under test, sensitivity to the internal features declined most rapidly. This age-related deficit cannot be explained by a general decline of visual or cognitive functioning as sensitivity to shapes was unaffected by aging. Further, equivalent inversion effects indicate that all participants employed the same holistic face processing strategies. Overall, these results suggest that ageing reduces sensitivity within the neural mechanisms which underlie face discrimination.

Acknowledgement: AJL is supported by the College of Optometrists Research Fellowship Award.

33.3045 Domain-general individual and developmental differences in confidence acuity

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To appropriately interact with the world, we must always consider how certain or confident we are in our thoughts and actions. Here, we examine whether individual and developmental differences in our sense of confidence – the perceived certainty of our decisions – is domain-general or domain-specific across three dimensions: number, area, and emotion perception. In two experiments, we measured observers' confidence acuity - their ability to discriminate between two internal confidence states – by asking them to choose which of two presented trials they are more confident in. By varying the difference in the difficulty between the two trials, we identify participants who can only detect very large differences in confidence (e.g., not at all sure vs. very sure) and participants who can detect even small differences in their confidence (e.g., sure vs. very sure). In Experiment 1, participants first completed three discrimination tasks: in the Number Task, participants saw groups of blue and yellow dots and indicated which was more numerous; in the Area Task, participants saw a blue and a yellow amorphous blob, and indicated which one is bigger; in the Emotion Task, participants saw two faces side-by-side, and indicated which face is happier (Fig1). Participants then complete a Confidence Discrimination version of these three games. In Experiment 2, 5-8 year-old children completed child-friendly versions of these tasks. Replicating previous results, we found little-to-no correlation between the three discrimination tasks. In strong contrast, however, we found very high correlations in the confidence discrimination tasks for all three dimensions – i.e., participants who could detect fine differences in confidence in the Number task also could detect fine differences in the Area and Emotion tasks, and vice-versa. These results held developmentally, and suggests that the ability to evaluate confidence is part of a domain-general system for representing confidence.

33.3046 The activation of the temporal area during audiovisual material matching in infants.

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For material perception, audition also provides useful information as well as vision and haptics. A previous study showed that adults can judge an object's material by perceiving the visual appearance of one material is combined with the impact sound of the same material (Fujisaki et al., 2014). However, its development has been little understood. This study examined the brain activity in response to audiovisual material matching in fifteen 4-8 month-olds Japanese infants, using functional near infrared spectroscopy (fNIRS). We measured cerebral hemoglobin concentrations in bilateral temporal brain regions, included the superior temporal sulcus (STS) area which is known to be critical for supra-additive processing of auditory and visual information (e.g., Calvert et al., 2000). We used two materials (wood and metal, used in Fujisaki et al. (2014)) and set two consistency conditions; for example, a match stimulus of "wood" material is the impact sound of wood paired with the visual appearance of wood, while a mismatch stimulus of "wood" is the impact sound of wood paired with the visual appearance of metal. Our results showed that a cerebral activation in the right temporal region increased when infants observed match stimuli of "wood" material as compared to baseline. Furthermore, such activation in the right temporal region was also observed in 4 month-olds infants. On the other hand, for "metal" material, a cerebral activation in the right temporal region increased significantly only in 7 month-olds infants. These findings suggest that the right temporal region plays a role in the processing of audiovisual material matching. In addition, 4 month-olds infants developed the neural mechanism underlying material perception, but its development might depend on a material's familiarity.

33.3047 Infants' face detection in natural scene

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In adult studies, it has been reported that human make use of non-facial scenic information for detecting faces (Lewis & Edmonds, 2003; Lewis & Edmonds, 2005). That is, detection of a face is significantly faster when a face appears in an intact scene than when a face appears in a scrambled scene. This suggests that we process scenes in parallel, and use the information from scene in a pre-attentive manner to detect the presence of face. In the developmental studies, previous studies have reported that infants prefer the upright face over inverted face, suggesting the early emergence

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of face detection. However, these previous studies presented faces in isolation from scenes, and little is known about development of infants' face detection in natural scene. Therefore, the aim of this study was to investigate whether infants utilize scenic information when they detect a face, as shown in adults. To this end, we examined 4- to 7-month-old infants' visual preference for upright image than for inverted one in two conditions: intact (a face occurs in an intact scene) and scrambled (a face occurs in a scrambled scene). In each condition, infants saw three different images. We found that 6- and 7-month-old infants preferred the upright image only in intact scene, but not in scrambled scene. However, only 7-month-olds showed significant difference between intact and scrambled scene in upright image preference. In contrast, 4- and 5-month-old infants showed upright image preference both in intact and scrambled scene. In sum, younger infants detect face regardless of whether the scene is intact, whilst older infants detect face only in intact scene. Our results suggest that infants aged over 7 months would process scenic information in pre-attentive manner in order to detect faces.

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33.3048 **Infants' neural response to yawning: a behavioral and a near-infrared spectroscopic study** Shuma Tsurumi[1](perry.super178@gmail.com), So Kanazawa[2], Masami Yamaguchi[1]; [1]Department of Psychology, Chuo University, [2]Department of Psychology, Japan Women's University

Yawning, an evolutionary facial expression, is contagious in human adults (Schurmann et al, 2005). Although previous study has shown that infants do not show contagious yawning (Millen and Anderson, 2011), it remains unclear whether infants perceive yawning like other facial expressions of emotion. In this study, we first investigated whether infants could discriminate between yawning and other mouth movements by using the preferential looking method. Second, we measured the infants' hemodynamic response to presentations of yawning and other mouth movements with near-infrared spectroscopy (NIRS) in order to examine the neural processing in their temporal areas. We hypothesized that yawning would induce higher activation in the temporal areas, which are sensitive to facial expressions of emotion. In Experiment 1, we tested 3- to 8- month-old infants' visual preference for the yawning movement as compared to the mouth movement. We presented yawning and mouth movements, tongue moved sideways against cheeks, of two females, side by side, and found that all infants showed significant preference for the yawning over the mouth movement, but that such preference disappeared when these two movements were inverted. These results suggest that infants discriminate between the yawning movement and the mouth movement from 3 months of age. In Experiment 2, we measured 5- to 8-month-old infants' hemodynamic response in the bilateral temporal areas during the presentation of yawning and mouth movements. In each trial, infants were presented with a sequence of two different females' facial movement. The hemodynamic response to the yawning and the mouth movement were contrasted against the activation during the baseline period. We found that 5- to 8- month-old infants showed higher activation for yawning than the mouth movement in the bilateral temporal areas. This indicates the possibility that the bilateral temporal areas are involved in the processing of yawning perception in infants.

33.3049 **Is this the same face? Developmental increases of the tolerance of within-person variability in the fusiform face area** Marisa Nordt[1](marisa.nordt@gmail.com), Kilian Semmelmann[1], Erhan Genç[2], Sarah Weigelt[1]; [1]Developmental Neuropsychology, Ruhr-Universität Bochum, [2]Biopsychology, Ruhr-Universität Bochum

The ability to discriminate and recognize faces undergoes prolonged development from childhood to adulthood, thereby raising the question which neural underpinnings are driving this development. So far, most research has focused on the ability to discriminate between faces (between-person variability), and there is first evidence, that the development of perceptual discriminability of face identity is correlated with increased neural sensitivity to face identity in face-selective regions. Here, we address the development of the neural foundation of the ability to recognize a face despite changes in appearance (within-person variability). Fourteen children (ages, 7-10) and 14 adults (ages, 20-23) watched series of images of either the same of different faces in a functional magnetic resonance imaging (fMRI) adaptation paradigm. Importantly, images of the same face could either be exact repetitions of an image or include different images of the same face (within-person variability). In addition to fMRI, a subset of participants completed a behavioral task, in which they had to decide if the face in two consecutively presented images belonged to the same person. Results from region of interest analyses based on both a functional as well as an anatomical approach replicate age-related increases in neural sensitivity to face identity in the fusiform face area (Natu et al., 2016). Most importantly, however, our results show that this sensitivity was less tolerant towards within-person variability - as indicated by less adaptation for different images of the same person - in children compared to adults. Crucially, the amount of adaptation to face identity despite within-person variability was correlated with the behavioral ability to recognize individual faces despite changes. In sum, our results suggest that increases of the tolerance of within-person variability in face-selective regions are related to the development of face recognition skills.

PERCEPTION AND ACTION: GRASPING

Sunday, May 21, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.4001 **Neural mechanisms for updating grasp plans: An fMRI study** Bianca Baltaretu[1,2,3](brb@yorku.ca), Simona Monaco[1,4], Ada Le[1,5], Jena Velji-Ibrahim[1], Gaelle Luabeya[1], J. Crawford[1,2,3]; [1]Centre for Vision Research, York University, Toronto, Ontario, Canada, [2]Vision: Science to Applications (VISTA) program, York University, Toronto, Ontario, Canada, [3]Neuroscience Graduate Diploma Program, York University, Toronto, Ontario, Canada, [4]Centre for Mind/Brain Science, University of Trento, Trento, Italy, [5]BEworks, Toronto, Ontario, Canada

Reach and grasp plans must adapt to both externally and internally imposed changes. For example, a number of studies have considered mechanisms for updating reach direction plans in light of object location changes (Pelisson et al., 1986) or internally generated changes in eye orientation (Medendorp et al., 2003). In comparison, less is known about how grasp plans are updated in light of external and internal changes (Le et al., 2014). Here, we used an fMRI-adaptation inspired protocol to investigate cortical mechanisms for updating grasp plans during changes in object orientation and/or gaze location. In each trial of our paradigm, participants (n=5, four of which met our criteria) were instructed to always fixate on the LED that was on. An oriented object (0° or 135°) was illuminated twice. Across the two illuminations, the object was presented at the same orientation (Repeat condition) or different orientations (Novel condition). After the second illumination of the object, participants were required to grasp the object. We analyzed the second illumination period to identify areas that change the grasp plan based on: 1) feature parameters (Novel Orientation > Repeat Orientation) and 2) spatial parameters (Novel Visual Field (VF) > Repeat VF). Preliminary results suggest that the Novel > Repeat condition recruits cuneus, precuneus, right posterior lingual gyrus, bilateral superior temporal sulcus, left inferior parietal superior frontal gyrus. In contrast, the Novel VF > Repeat VF condition implicates bilateral anterior lingual gyrus, right inferior occipital gyrus, bilateral superior occipital gyrus, left primary motor cortex and right superior frontal gyrus (including frontal eye fields). Overall, the brain regions involved in processing spatial properties tap into the occipital (visual)- frontal (motor) network, whereas feature properties activate areas along the occipito-temporal and occipito-frontal pathways. Our future analysis will focus on the intersection of these mechanisms for the updating of object orientation across eye movements.

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33.4002 **Decoding real and imagined actions: overlapping but distinct neural representations for planning vs. imagining hand movements** Simona Monaco[1](simona.monaco@gmail.com), Giulia Malfatti[1], Jody Culham[1,2], Luigi Cattaneo[1,3], Luca Turella[1]; [1]Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy, [2]Brain and Mind Institute, University of Western Ontario, London, Ontario, Canada, [3]Department of Neurological, Neuropsychological, Morphological, and Movement Sciences, University of Verona, Italy

Patients with motor impairments learn to use brain-computer interfaces with training that consists of imagining what they want the effector to do. Neurologically intact individuals use motor imagery to improve performance of acquired skills and acquisition of new ones. The effect of motor imagery on real actions might be related to a shared neural representation of real and imagined actions. We explored whether areas implicated in hand actions and imagery tasks have a shared representation for planning and imagining hand movements. In a slow event-related functional magnetic resonance imaging (fMRI) paradigm participants (N=16) performed or imagined performing actions with the right dominant hand towards a centrally located object composed of a small shape attached on a large shape. The actions consisted of grasping the large shape, grasping the small shape, or reaching to the center of the object while fixating a point above the object. Each trial started with an auditory cue instructing participants about the task (Imagery, Movement) and the action (Grasp large, Grasp small, Reach-to-touch) to be performed at the end of the trial. A 10-s delay was followed by a go cue to perform or imagine performing the action (Go phase). Importantly, for both Imagery and Movement only the object, but not the hand, was visible to the participants. Using multi-voxel pattern analysis, we decoded action type in the planning phase of Movement tasks as well as in the Go phase of Imagery tasks in the anterior intraparietal sulcus (aIPS) and in early visual cortex (EVC). Moreover, we found cross-decoding between planning and imagery in aIPS, but not in EVC. Our results suggest a shared representation for planning and imagining specific hand movements in aIPS but not in low-level visual areas, such as the EVC. Therefore, planning and imagining actions have overlapping but not identical neural substrates.

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33.4003 **A new multivariate analysis method suggests timing is key factor in visually-guided reach-to-grasp movements** Alex Yan[1](alexyan3000@gmail.com), Jody Culham[1]; [1]Brain and Mind Institute, Western University

INTRODUCTION: Visually guided reach-to-grasp actions have been proposed to consist of distinct transport and grip components, which may result from the different visual properties required to guide them (location and object size and shape, respectively). However, kinematic studies of hand actions have typically investigated the effect of different conditions on dependent measures one at a time. We examined the interrelationships between various kinematic variables using a multivariate approach. In addition, we developed new measures of grip accuracy and tested how these related to standard reach-to-grasp variables. METHODS: Participants (n=24) performed reach-to-grasp or reach-to-touch movements upon different-sized rectangular objects. Our analysis involved correlating standard kinematic variables (e.g., maximum grip aperture, MGA, and peak velocity of reach, PV, and time at which they occurred, tMGA and tPV) and new grip accuracy variables (shift and orientation of initial grip) with one another across all trials for each subject. We applied a multivariate analysis [using similar logic as representational similarity analysis (RSA) used in fMRI] to test various models of reach-to-grasp components, including a transport-grip model which predicts strong correlations within (but not between) traditional transport and grip and a timing-based model which predicts strong correlations between variables associated with the timing of movement. RESULTS: Our timing-based model of reach-to-grasp movements, but not the transport-grip model, showed strong correlation with the data. Furthermore, as opposed to our hypothesis, participants did not display larger grips on trials where their grip accuracy was low. CONCLUSION: Though standard kinematic measures used in studying reach-to-grasp movements (e.g., PV, MGA) have been theoretically divided into transport and grip variables, these variables do not explain the relationships between variables. The development of new measures of grip accuracy and new applications of multivariate analyses open up new questions for kinematic studies of reach-to-grasp movements in clinical populations and healthy controls.

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33.4004 **On-line adjustments of grasping movements under visual, haptic and visuo-haptic guidance** Ivan Camponogara[1](ivan.camponogara@nyu.edu), Robert Volcic[1]; [1]Department of Psychology, New York University Abu Dhabi

A sudden change of object properties during reach-to-grasp actions requires a fast update of the motor commands, which rely on the available sensory feedback during movement execution. While the role of visual feedback in on-line movement adjustments has been widely studied, far less is known about the contribution of other sensory systems. In particular, are the adjustments to haptically-sensed perturbations as fast as those found in vision? And, does the combined visuo-haptic information lead to even faster adjustments? In the present study, participants were asked to reach and grasp an object with their right hand while the object's size was occasionally perturbed during the movement. The availability of sensory feedback was modulated in three different conditions. In the visual condition, participants had full vision. In the haptic condition, the actions were under the guidance of haptic information from the left hand, while vision was prevented. In the visuo-haptic condition, participants had access to the combined visuo-haptic information. We found that haptic and visual conditions were similar in movement duration, but differed in terms of their kinematic properties. In the haptic condition, movements were faster in the initial phase, whereas in the visual condition, movements were faster in the final phase. Nevertheless, the grasp adjustment times to perturbations were similar (~200 ms). In the visuo-haptic condition, instead, the availability of both visual and haptic information reduced movement duration by ~80 ms and shortened the grasp adjustment time by ~50 ms. Our findings demonstrate that even though the available sensory information influences the action kine- matics, haptic input is as effective as the visual input to quickly perform on-line movement adjustments in response to a perturbation. Moreover, the combination of both inputs not only leads to faster movements, but it also speeds-up the reactions to sudden perturbations.

33.4005 **The contributions of visual and tactile cues to analytic processing during grasping** Aviad Ozana[1](ozanaaviad@gmail.com), Tzvi Ganel[2]; [1]Department of Psychology, Ben-Gurion University of the Negev, Israel.

Visually-guided actions toward real objects are characterized by distinguishable hand gestures. For example, finger kinematics during grasping violate Weber's law, a basic relative principle of visual perception, which implies that visuomotor control is governed by analytic processing of object size. Unlike for real objects, movement trajectories toward 2D line drawings of objects adhere to Weber's law. It can be argued therefore, that when actions are directed to 2D objects, the visuomotor system fails at operating in its normal analytic processing style and is distracted by irrelevant perceptual information. Here, we studied the visual and tactile cues that enable analytic processing during grasping. In Experiment 1, we tested the role of richness in pictorial details. To this purpose, visually-guided actions directed toward 3D objects were compared with actions directed toward high resolution photos of the objects. As for line drawings, actions directed at photos adhered to Weber's law, suggesting that richness in visual details does not contribute to analytic processing. In Experiment 2, we tested the role of tactile feedback from the object. Participants were asked to direct grasping movements toward real objects placed beyond a glass. Grasping movements were terminated with touching the glass flat surface. Surprisingly, although tactile feedback was denied, grasping was still performed in a normal, analytic manner, violating Weber's law. This indicates that tactile feedback is not necessary for analytic processing. In Experiment 3, a similar apparatus was used, but now participants were asked not to touch the glass surface at the end of the movement. Grasping trajectories now adhered Weber's law. Taken together, these findings suggest that analytic processing during grasping does not depend on tactile feedback from the object. Indeed, visual presentation of 3D objects combined with uninformative haptic information from touching a flat surface are sufficient to enable effective analytic processing during grasping.

33.4006 **Effects of numerical magnitude on the online execution of grasping movements** Gal Namdar[1](namdargal@gmail.com), Tzvi Ganel[1]; [1]Department of Psychology, Ben-Gurion University of the Negev, Beer-Sheva, Israel.

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Recent literature has established a directional influence of numerical magnitude on actions performed towards neutral objects. Such influence is illustrated by larger apertures during grasping following the presentation of large compared to small digits. The interaction between visuomotor control and magnitude has been commonly attributed to the planning stage of the action prior to motor execution. However, this assumption has not been directly empirically tested. In two experiments, we tested whether the effects of numerical magnitude on grasping derive from action planning or from action execution. Participants were asked to grasp an object following a short visually (Experiment 1) or auditory (Experiment 2) presentation of a small (1/2) or a large (8/9) digits. Grasping in both experiments was performed under either closed-loop (CL) or open-loop (OL) conditions, for which online vision was prevented during action execution. As expected, digit magnitude affected grip apertures in the CL condition, when online vision was allowed. However, magnitude had no effect on grip aperture in the OL condition. This pattern of results suggests that the effects of numerical magnitude on action originate from interactions between numerical magnitude and object size during the online execution of actions. Unlike previously assumed, the findings also suggest that the effect of magnitude on visuomotor does not result from a motor planning stage prior to action initiation.

33.4007 Relation between action precision and perceptual discrimination

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Previous studies have demonstrated that performing an action toward an object can impact the visual perceptual processing of that object. For instance, the congruence between hand movements and visual stimuli improves visual discrimination performance. In our recent work, to examine how easiness of action influences perceptual sensitivity, we asked participants to perform an orientation change detection task using a titled Gabor patch, while preparing a point-to-grasp movement towards it. We observed that when they grasped a right-titled patch with their dominant right hand, which was easier than grasping a left-titled one, orientation discrimination was better. Here, we extended this observation to when grasping was performed with the non-dominant hand. We also examined whether orientation discrimination sensitivity could be further enhanced with training of grasping precision. To address this question, we compared the orientation discrimination sensitivity before and after an action training session, in which participants were required to grasp various titled objects. We found that the magnitude of grasping accuracy improvement in the action training session was positively correlated with the improvement of the orientation discrimination. The effect, however, was not observed with perceptual training in the absence of action. In conclusion, we suggest that the easiness of action as well as training of action precision can influence the sensitivity of perceptual discrimination.

33.4008 Visualization of viewing strategies for grasping a rotating target

Charlotte Leferink[1](leferink@myumanitoba.ca), Neil Bruce[1], Jonathan Marotta[1]; [1]University of Manitoba

Grasping a rotating target necessitates that visuomotor strategies be repeatedly updated as new grasp sites come into play. Our previous investigations have shown that we do not simply track a single location on a rotating target prior to grasping it. Rather, gaze fixations continually relocate to the top edge of the target. Tracking strategies vary depending upon the speed of the target's rotation, with faster speeds resulting in fixations closer to the centre of mass of the target (Leferink & Marotta, 2015). In order to gain further understanding of viewing strategies, visualizations were employed to evaluate at which orientations of the target did gaze fixation relocate, and how speed and direction of target rotation influenced the distributions of gaze on the target. A 2D rectangular target was rotated at one of 4 speeds around its centre of mass, in either direction. After a delay of 3.5s, participants reached out and 'grasped' the target. A heat map analysis indicated the likelihood of fixating the target through probabilistic distributions of gaze location, from which the differences between the distributions at certain time points and across the conditions were evaluated. Characterizations of various viewing strategies suggest that distributions of gaze location were influenced by kinematic and oculomotor constraints differently across the target conditions. Slower rotational speeds allowed for the tracking of a 'graspable' position on the target, whereas faster speeds increased the task difficulty resulting in gaze locating more frequently near the target's centre of mass. An interaction between the direction and speed of target rotation showed that the direction of rotation was more influential during slower speeds of rotation. The results also suggest that a common viewing strategy for grasping a rapidly moving target is to utilize parafoveal vision in order to adapt to oculomotor constraints.

33.4009 You break it, you buy it – effect of object shape on grasp locations

Lina Klein[1](Lina.K.Klein@psychol.uni-giessen.de), Vivian Paulun[1], Roland Fleming[1]; [1]Department of Psychology, Justus-Liebig University Giessen

Successfully interacting with objects requires choosing appropriate grasp locations. By taking into account an object's shape, material properties, and the desired action, humans identify stable, comfortable grasp points that minimize slippage and torsion. The "contact point selection model" (Kleinholdermann et al., 2013) successfully predicts precision grip grasping for a range of two-dimensional objects. However, the rules determining grasp point selection for three-dimensional objects remain unclear. In this study, we tested how an object's visually perceived shape affects precision grip grasp locations. We created four differently shaped objects each out of 10 wooden cubes (2.5 cm^3), which were presented to right-handed participants in either of two orientations. Starting at one of two different start locations, the participants' task was simply to pick each object up with finger and thumb, and place it on an elevated plate. An Optotrak system allowed us to track participants' fingertips as they reached for, grasped, and handled the objects. Results showed that the object's center of mass (COM), partial object occlusions by the subject's hand, and shape properties like the presence of handles played a role when choosing grasp locations. We found that timing of movements towards and while holding the objects was influenced by the objects' particular shape. Results showed that grasp locations were influenced by object shape, e.g. where a handle (cubes stacked on top of each other) was conveniently placed, it would be grasped without regard for large deviations from the COM. Objects without such handles showed grasp points located further toward the COM. These findings provide initial constraints on a generalized contact point selection model for 3D objects. In turn, such a model also has implications for the visual representation of 3D shape.

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33.4010 Influence of object texture on grasping behaviour

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When picking up objects using a pinch-grip there are often numerous places at which one could place the thumb and index finger, yet people seem to be consistent in where they place them. They grasp objects in such a manner that a line connecting the fingers would pass through or above the object's centre-of-mass (COM), presumably in order to minimize torque and therefore the required grip force. However, the required grip force does not only depend on the torque but also on the object's shape, its weight and the surface friction at the points at which it is grasped. Here we investigate whether participants adjust their grasping points if the surface near the COM is slippery while off-centre areas are not. Doing so would increase the torque but decrease the grip force that is required to prevent slipping. Participants were asked to lift polished aluminum bars, while their grasping points were recorded. The bars were oriented horizontally, with their center aligned with the participants' body midline. Two different bar lengths were used: 26cm and 13cm. One end of each bar was covered with anti-slip tape. The bars varied in the horizontal offset between the COM and the edge of this high friction area with offsets of 0, 1 and 2cm. Fully covered bars and bars without any anti-slip tape served as control conditions. We examined whether participants grasp further off-centre in the direction of the high friction area. The slipperiness of the surface affected the height of the grasping points, indicating that participants were aware of the difference in friction. Nevertheless, the influence on the primary measure

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of interest, the horizontal grasping location, was minimal. This shows that the judged COM largely determines how an object is grasped, with limited importance given to surface friction.

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33.4011 Grip control and contact point selection for grasping slanted 3D objects with conflicting monocular and binocular cues Zhongting Chen[1](albertchen188@gmail.com), Jeffrey Saunders[1]; [1]Department of Psychology, the University of Hong Kong

We investigated how monocular and binocular cues contribute grasping a slanted 3D object, and whether grasping performance was consistent with perception. Depth information is needed for multiple purposes: aligning the grip with the orientation of the object, scaling the grip aperture, and selecting grasp contact points for a stable grip. We measured these components when subjects reached to grasp objects that presented conflicting 3D cues, and measured perceived slant for comparison. Consistent cue stimuli were square planar objects presented at different slants and plane orientations. For conflict conditions, we created objects that, when viewed at a 45° slant, had the same projected contour as a rotated square object that is slanted by 55° (compressed) or 35° (elongated). For these objects, contour information specifies an incorrect 3D slant and orientation. Slant estimates revealed that perceived slant of cue conflict objects was between the slant specified by contour and binocular cues. When subjects' grasping these objects, the hand orientation was consistent with perceived slant: the grip was less slanted as the hand approached elongated objects, and vice versa. Grip aperture was similarly intermediate between the size specified by contour and binocular cues. However, the contact points for grasping objects were not influenced by binocular cues. Grasp points were consistent with a rectangular interpretation of the projected contours, rather than a skewed object that would be consistent with an intermediate slant. While this is not consistent with perceived slant, it would be consistent with perceived shape of the cue conflict stimuli, which appear to be elongated or compressed rectangular objects. We observed no dissociation between the use of 3D cues for perception and action. Grip control and grasp points were affected by 3D cues in the same way as perceived slant and shape.

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33.4012 Features of grasp adaptation: Error correction, interference, and perceptual recalibration Evan Cesanek[1](evan_cesanek@brown.edu), Fulvio Domini[1,2]; [1]Department of Cognitive, Linguistic, and Psychological Sciences, Brown University, [2]Center for Neuroscience and Cognitive Systems@UniTn, Istituto Italiano di Tecnologia (IIT)

The human sensorimotor system readily adapts itself to altered relationships between visual appearances and physical reality. While adaptation of reaching movements has been extensively studied, it is unclear whether known features of reach adaptation can be generalized to grasp adaptation. In a series of experiments in which participants grasped objects that could appear larger or smaller than their physical sizes, we investigated multiple characteristics of grasp adaptation, including (1) error correction rates, (2) interference caused by interleaving positively perturbed (visual > physical) and negatively perturbed (visual < physical) targets at separate spatial locations, (3) functional asymmetries in adaptation and planning processes, (4) transfer to a cross-modal perceptual task (manual size estimation, MSE), and (5) effects on visual perception. In the single-perturbation experiments, the maximum grip aperture (MGA) gradually adapted to positive and negative perturbations. In the conflicting-perturbations experiment, interference was reduced when the distance between the two target locations was increased. However, participants were unable to fully adapt to both perturbations even in the increased-separation condition. Neither of these studies yielded clear evidence for an asymmetry in adaptation, as suggested previously, but they did reveal an asymmetry in the initial responses to perturbations: the initial MGA increase elicited by positive perturbation was greater than the initial MGA decrease elicited by negative perturbation. Finally, in the MSE experiment, we found a clear asymmetry in transfer of adaptation: MSEs increased following adaptation to a negative perturbation (requiring larger MGAs), but they did not decrease following adaptation to a positive perturbation. This transfer was slightly strengthened when MSEs were given in the same location as the grasp targets. We interpret these findings as evidence that reach and grasp adaptation are generally similar processes relying on flexible visuomotor mappings, but they differ due to their dependence on specific task constraints and movement feedback signals.

33.4013 Error correction and interference in grasping illusions Karl Kopiske[1](karl.kopiske@gmail.com), Evan Cesanek[2], Carlo Campagnoli[2], Fulvio Domini[1,2]; [1]Center for Neuroscience and Cognitive Systems@UniTn, Istituto Italiano di Tecnologia (IIT), [2]Department of Cognitive, Linguistic and Psychological Sciences, Brown University

There is a long-standing debate about whether pictorial illusions affect grasping, and to what degree. More recently, many studies have reported at least some effect of illusions on grasping, but also frequently a rather rapid decrease of the illusion effect on grasping over trials. Such a pattern is quite similar to what is typically found in studies on sensorimotor adaptation, and may be a consequence of participants learning to counteract illusory size distortions. If this were the case, one would expect adaptation to be slower or non-existent when opposite distortions are presented repeatedly in random order in the same location. To investigate this, we conducted a grasping experiment (N=40) using the Müller-Lyer illusion with incremental and decremental Müller-Lyer illusion displays presented either in (1) one block in pseudo-randomized order, or (2) two separate blocks of only one illusion type each. As predicted, we found an illusion effect on the maximum grip aperture, but a decrease of the illusion effect over trials as well as different decrease rates for single-illusion blocks and intermixed blocks. We applied a linear state-space error-correction model in which the illusion configuration was regarded as a constant visual size perturbation that determined the error signal. Our model was nicely able to qualitatively predict the data by assuming constant illusory perturbations, along with error-correction and some, but not full, error-generalization between illusion configurations. Consistent with the predictions of error-correction, we also found adaptation aftereffects and previous-trial effects of illusion configuration, but not of object size. This suggests that error-correction may be able to explain not only decreasing illusion effects, but also why some studies have found no such decreases.

Object Recognition: Foundations

Sunday, May 21, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.4014 An Investigation of the Characteristic Properties of Cognitive Processes with Perceptually Integral Stimuli Yanjun Liu[1](yanjun1130@gmail.com), Ru Zhang[3], James Townsend[1], Michael Wenger[2], Lisa De Stefano[2]; [1]Indiana University Bloomington, [2]University of Oklahoma, [3]University of Colorado Boulder

General recognition theory (GRT, Ashby & Townsend, 1986) is a nonparametric generalization of signal detection theory that characterizes possible dependencies in perceptual representation in terms of the presence or absence of violations of perceptual independence (PI), perceptual separability (PS) and decisional separability (DS), using response-frequency-based measures obtained in a complete identification (CID) paradigm. Systems factorial technology (SFT, Townsend & Nozawa, 1995) is a nonparametric theory that characterizes the fundamental properties of information processing (architecture, stopping rule, capacity, and independence) using reaction-time (RT) obtained in a double factorial classification paradigm (DFP). The present study applied both GRT and SFT using a set of rectangular stimuli whose width and height were varied; these stimuli have previously been shown to be perceived in a perceptually integral manner (Macmillan & Ornstein, 1998). In addition, we manipulated response bias by running both tasks first using payoff matrixes designed to encourage unbiased respond and second using payoffs biased toward specific stimuli, testing the hypothesis that the combined use of GRT and SFT would allow for converging sources of evidence regarding inferred perceptual representations and processing characteristics. Results suggest observers (N = 4) violated PS in both the unbiased and biased conditions, and that parallel exhaustive processing was implicated for all observers in the unbiased condition and for three of four observers in the biased condition. The violation in PS indicated by GRT and the parallel exhaustive processing indicated by SFT document strong evidence to support previous findings of perceptually integral processing of rectangular stimuli and provided converging inferences by both theories, including consideration of individual differences. This coherent characterization of perceptual integral manner by both

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theories suggests a strong potential in the combination of GRT and SFT, allowing a more complete picture of information processing to be developed, including principled accounts of individual differences.

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33.4015 **On the Human Visual System Invariance to Translation and Scale** Yena Han[1](yenahan@mit.edu), Gemma Roig[1,2], Gadi Geiger[1], Tomaso Poggio[1]; [1]Center for Brains, Minds and Machines, Massachusetts Institute of Technology, [2]LCSL, Istituto Italiano di Tecnologia at MIT

Humans are able to recognize objects presented at different scales and positions. Numerous behavioral studies on object recognition of translation transformations provided inconsistent results. It was argued that this may be due to differences in the nature of the stimuli used in their experiments, such as spatial frequency or shapes of the objects. Recognition of objects at different scales and positions can take place trivially because of previous experience and memorization of several transformed images of the object. It is however likely that we can also recognize specific objects seen only once at different positions and scales. To characterize this "single-shot" invariance, we use letter-like stimuli that are unknown to the tested human subjects, and we also use known letters for comparison. We analyze the recognition performance in a same/different task presenting the characters on a display for 33ms at different scales and positions. This allows us to compare the recognition performance using familiar and unfamiliar letters that are of similar nature in terms of spatial frequency and shape. Our data suggest that the feedforward path of the human visual system computes a representation of objects that are scale invariant. We also observe limited position invariance, the extent of which increases linearly with scale. The recognition accuracy is higher in the set-ups when the unknown characters are first shown at the fovea and tested at the periphery, and when shown and tested at opposite sites of the visual field, compared to when shown first at the periphery and tested in the fovea.

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33.4016 **Effects of Inducer Contrast on Simultaneous Brightness and Poggendorf Illusions** Bruno Breitmeyer[1](brunob@uh.edu), James Brown[2], Ralph Hale[2], Richard Plummer[2]; [1]Department of Psychology, University of Houston, [2]Department of Psychology, University of Georgia

While the striate cortical contrast-response function is nearly linear, the extrastriate function shows a steep, nonlinear increase for contrasts ranging from 0.0 to 0.30 and a gradual increase toward response saturation for higher contrasts. The extrastriate response comports with: 1) the tendency for neural activity in the ventral cortical pathway to shift from stimulus-, energy-dependent coding at low cortical levels to percept-, information-dependent coding at higher levels; 2) the majority (≈70%) of local contrasts in natural scenes being ≤ 0.30; and consequently, 3) the need to amplify the contrast response to the low-contrast inputs at higher percept-dependent cortical coding to optimize the extraction of perceptual information. Past research has shown that Simultaneous Brightness induction can be explained by the antagonistic center-surround organization of neural receptive fields at low (striate and pre-striate) levels of processing whereas the Poggendorf illusion appears to additionally rely on higher percept-dependent (post-striate) processing. As inducer contrast increases from 0.0 to 0.30, the Poggendorf illusion should yield a strong nonlinear increase whereas the Simultaneous Brightness illusion should yield a nearly linear increase over the same range of contrasts. We normalized contrast-dependent changes of both illusions so that the changes ranged from 0.0 (at inducer contrast = 0.0) to 1.0 (at inducer contrast = 1.0). As expected, for inducer contrasts ranging from 0.0 to 0.32, we found that the illusion magnitude increased steeply and nonlinearly with inducer contrast for the Poggendorf illusion but nearly linearly for the Simultaneous Brightness illusion. We conclude that 1) the Poggendorf illusion relies more heavily on high-level, percept-dependent cortical processing than the Simultaneous Brightness illusion and, more generally, 2) differences between contrast-dependent changes may be a useful tool in determining the relative level of cortical processing of many other visual effects.

33.4017 **A Dissociation Between Visual Strategy Use and Accuracy after Perceptual Expertise Training** Allison Carr[1](acarr5@ufl.edu), Travis Jones[1], Andrea Cataldo[2], Hillary Hadley[3], Erik Arnold[2], James Tanaka[4], Tim Curran[5], Lisa Scott[1]; [1]University of Florida, [2]University of Massachusetts Amherst, [3]Northeastern University, [4]University of Victoria, [5]University of Colorado Boulder

A perceptual expert is skilled at observing, identifying, and distinguishing between items within their domain of expertise. Previous research examining perceptual expertise with birds (Scott et al., 2006) and cars (Scott et al., 2008) suggests that subordinate-level training improves perceptual discrimination over basic-level training. However, it was previously unclear whether changes in accuracy were accompanied by changes in visual strategy use. To answer this question, adults (n= 32) received 9 hours of training with 2 families of computer-generated objects over a 2-3 week period. Each family included 10 unique species (labeled "A" through "J") each containing 12 exemplars. Within subjects, one family was trained at the subordinate level and the other family was trained at the basic-level. Stimulus features, including color and spatial frequency, were also manipulated to assess the impact of these factors on posttest discrimination. Pre- and posttest assessments included eye-tracking and accuracy (d') during a serial image discrimination task. Consistent with previous reports (Scott et al., 2006; 2008), accuracy (d') increased from pretest to posttest for the subordinate trained family but not for the basic trained family (See Figure 1, top left). Eye-tracking results suggest that although training did not change overall dwell time, the average fixation duration increased and the number of fixations decreased from pretest to posttest (Figure 1). These changes in visual strategies were unrelated to the level of training and the image manipulations did not impact these results. Improvements in perceptual discrimination replicate previous expertise training results. Although behavior is differentially impacted by subordinate versus basic level training, the eye tracking analyses suggest that changes in visual strategies do not differ based on level of training.

33.4018 **The role of context and level of object processing in the activation of structure- and function-based action representation** Wenyuan Yu[1,2](yuwy@psych.ac.cn), Ye Liu[1], Xiaolan Fu[1,2]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences, [2]University of Chinese Academy of Sciences

Recently research shows that activation of action representation is not always automatic, but influenced by some factors (Freeman, Itthipuripat, & Aron, 2016; Randerath, Martin, & Frey, 2013). Structure- and function-based action representations, which depend on distinct neural streams and represent different action information related to objects (Buxbaum & Kalénine, 2010), may be differently influenced by context and the level of object processing on their activation. In the present study, a behavioral experiment was conducted to explore whether structure- and function-based action representations could be activated in categorization task (low-level object processing) and naming task (high-level object processing). Participants were asked to categorize or name a photograph of an object preceded by a priming hand action video as quickly and as accurately as possible. The results showed that participants categorized the objects with congruent structure-based action faster than those with incongruent structure-based action, and this priming effect was significant only in the structure-based action priming block preceded by the function-based action priming block. Whereas, participants named the objects with congruent function-based action faster than those with incongruent function-based action. The findings suggested that the activation of structure-based action representation depended on the function-based action context□which may draw attention to the action information related to objects. The findings also suggested that low-level object processing in function-based action context was enough for the activation of structure-based action representation, and function-based action representation was only activated after high-level object processing. And the absence of structure-based action priming effect in naming task might be caused by the quick decay of structure-based action representation (Jax & Buxbaum, 2010). The present study provided further evidence for the activation condition of two action representations, and the distinction between the two action systems: "Grasp" and "Use" systems.

33.4019 **Distance perception and falling risks** Russell Jackson[1](rjackson@uidaho.edu), William Felton[1]; [1]Psychology Department, University of Idaho

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Falling regularly injures and kills more people worldwide than nearly any other accidental source. Evolved Navigation Theory suggests that such navigational outcomes shaped cognitive and locomotor mechanisms over evolutionary time. Evolved Navigation Theory has led to the discovery of some of the largest known distance illusions by identifying that evolutionarily relevant falling risks elicit distance perception biases. However, little research has investigated how Evolved Navigation Theory hypotheses apply to modern falling prevention. Here we investigated the extent to which modern safety barriers alter distance perception on surfaces with falling risks. In Experiment 1, participants in a virtual environment made four estimates. Participants were unaware that all estimates were of the same distance. These four estimates took place across surfaces that varied in falling risk and safety barrier composition. We used distance matching procedures and partially randomized orders with random assignment. Results indicated that participants overestimated, to a great extent, only the distances with falling risks. Further, distance estimates appeared to depend on the composition of safety barrier, but in a relatively minor fashion. However, participants estimated the entire surface length, which included the safety barrier in the estimate. This led us to parse estimates into two separate components in Experiment 2. Participants in this second experiment estimated the length (height) of falling risk surfaces separately from the height of the safety barrier. The results of this experiment confirmed that the falling risk manipulation likely accounted for the large distance estimate differences that we observed previously. Further, safety barrier composition appeared to account for the minor differences across falling risk surfaces. These results identify distance perception as a means for measuring safety risks in modern environments and that safety barrier composition likely alters perception and navigation of those risks

33.4020 The effect of hunger on the perception of food size

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The feeling of hunger is an inseparable part of our daily lives. Indeed, previous studies showed that hunger can have a significant influence on people's physiological and emotional state and on their everyday behavior. Yet, it is less clear whether and in which manner does hunger affect the way people perceive their external environment. Specifically, when people feel hungry - do they actually perceive food-related stimuli in a different manner? In two experiments, we examined the effects of hunger on perceptual biases, and more importantly – on the perceptual resolution of food size. We calculated the Just Noticeable Differences (JNDs) to measure the sensitivity to detect the smallest difference between two stimuli of differing sizes. The results of Experiment 1 showed that participants' resolution was higher to detect small changes in food size when they were hungry following a mild period of food deprivation. However, food deprivation did not lead to any directional biases in the average perception of food size. In Experiment 2, we replicated and extended the results of Experiment 2 to a different food stimulus. The results of the two experiments show that food deprivation affects the way people perceive their environment.

33.4021 Stimulus and task dependence of response latencies in primate area V4

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Latency of neuronal responses is influenced by stimulus saliency and context and can reflect hierarchical processing of visual information. In primate area V4, typical latency from stimulus onset is widely cited to be ~100ms (Schmolesky et al., 1998); however, this value was estimated from 29 units in one anesthetized animal. We examined onset latency in area V4 across multiple datasets gathered from 3 animals in our lab. Data were collected from single, well-isolated neurons in awake primates engaged either in a passive fixation task, as stimuli of different shapes, sizes and surface features were flashed within the receptive field of each neuron, or an active behavioral task, where animals reported their perceptual decision via saccadic eye movement. Thus, we were able to examine the effect of stimulus and task context on the timing of neural signals in V4. For each neuron, response latencies were calculated as the time for the neuronal response to reach half of its maximal value (in contrast, Schmolesky et al. performed Poisson spike train analysis). During passive fixation, V4 latencies ranged from 36ms to 195ms with a median value of 72ms across all neurons (n=291). Response latencies did not change as a function of stimulus shape, but were shorter for larger stimuli: median latencies increased from 51ms to 60ms for a fivefold difference in stimulus size (n=29), and for stimuli that included a surface fill as compared to outlines: median latency = 75ms versus 80ms (n=32). Latencies during fixation were slightly longer than during behavior: median latency = 72ms versus 67ms (p< 0.001, n=161). In conclusion, our results demonstrate that a majority of V4 neurons respond within 70ms of stimulus onset and confirm that V4 response dynamics depend on the visual stimulus as well as behavioral context.

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33.4022 New Optotypes for recognition acuity in children

Lisa Hamm[1](l.hamm@auckland.ac.nz), Janice Yeoman[1], Nicola Anstice[1], Steven Dakin[1]; [1]University of Auckland, Optometry and Vision Science

Introduction: Recognition of ten Sloan letters is commonly used to assess visual acuity in adults. For testing children, who may not be familiar with language based symbols, either letters with a matching card, or more familiar symbols are used. The currently recommended options for children are comprised of four, rather than ten optotypes. Larger sets are available, but these sets have less principled design. Our aim was to generate a set of ten non-language based symbols with consistent stroke width, aspect ratios. We designed the set to elicited similar thresholds and to vanish uniformly into a grey background when pseudo high pass filtering was applied. Methods: Inter-optotype variability was assessed with independent, interleaved Quest staircases on eleven visually normal adults. We ran repeated measures ANOVAs to assess statistical differences within regular and pseudo high pass (vanishing) versions of three optotype sets (newly developed, the EDTRS Sloan letter, and Landolt C's). Maximum threshold differences within each group were determined with post hoc analysis in cases of significant main effects. Results: All four sets which were comprised of unique optotypes had statistically significant inter-optotype variability. Post hoc analysis revealed the variance was smaller for the pseudo high pass than regular versions. The new set had less inter-optotype variability than the Sloan regular and the Sloan vanishing sets. The new vanishing version eliciting remarkably similar internal thresholds, and error analysis further suggested more uniform vanishing in the new set than within the pseudo high pass filtered Sloan set. Conclusion: The newly designing set of ten optotypes had less inter-optotype variability compared to that within the EDTRS Sloan letter set. As this set does not require familiarity with language symbols, application for recognition acuity measurement across age and culture should be explored.

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33.4023 Visual aspects of numeracy neuroimaging: cortical surface-based meta-analysis.

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INTRODUCTION: Neuroimaging research has identified regions in parietal cortex related to visual numeracy. In particular, the horizontal segment of the intraparietal sulcus (IPS) may be the site of domain-specific neural activity related to understanding numbers. Meta-analysis is invaluable for assessing reliability across studies, but it can be difficult to establish the precise cortical location of published neuroimaging coordinates that lie in deep cortical sulci like the IPS. We applied a meta-analysis technique that projects stereotaxic coordinates onto a cortical surface atlas to analyze the location of functionally significant regions across studies. METHODS: The Matlab toolbox VAMCA (Visualization And Meta-analysis on Cortical Anatomy; http:/nitrc.org/projects/vamca) uses a database of cortices from 60 healthy subjects to locate activations on a standardized cortical surface by extending the technique of multi-fiducial mapping. Here we used coordinates from over 100 published articles to examine the consistency of functional activations from numeracy tasks. We also compared differences in activation loci that corresponded to parameters that varied across studies, including cognitive demands (e.g. magnitude comparison vs. enumeration), visual displays (e.g. symbolic vs. analog depictions of numbers), and ranges of numbers (which interacts with perceptual grouping). RESULTS: Meta-analyses showed that a region in the horizontal segment of the IPS is activated during diverse kinds of number judgments. There was also evidence that symbolic (numerals) and analog (dots) representations activated relatively superior and inferior portions of the horizontal/anterior IPS. We identified subregions of occipitotemporal cortex that may respond selectively to lower (1-10) and higher (10-100) ranges. CONCLUSION: Cortical surface-based meta-analysis is useful for testing the reliability and generality of IPS effects discovered in recent numeracy neuroimaging studies. We propose that the different kinds of perceptual organization afforded by small and large sets of dots may engage lateral and inferior occipitotemporal regions, respectively, during numeracy tasks.

33.4024 Multivariate pattern analysis of MEG and EEG reveals the dynamics of human object processing

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Despite the increasing popularity of multivariate pattern classification methods for electrophysiological data, little is known about the decoding performance of MEG vs. EEG data. The two modalities measure electromagnetic signals from the same underlying neural sources, yet they have systematic differences in sampling neural activity. Here, we investigated the extent to which such measurement differences consistently bias the information coded in MEG and EEG signals in human visual object recognition. We conducted a concurrent MEG/EEG study while participants (N=15) viewed images of 92 everyday objects and compared MEG/EEG multivariate results in both time and space. Comparison in time relied on evaluating classification time courses directly, and via representational similarity analysis (RSA). Comparison in space relied on fusion of MEG/EEG data with fMRI data based on RSA. This enabled direct localization of MEG/EEG signals with independent fMRI data, bypassing the inherent ambiguities of inverse solutions. Single image classification revealed increased MEG sensitivity to early components (peak at 112ms, 95% CI: 109-124ms), versus increased EEG sensitivity to late components (peak at 181ms; 131-195ms). Despite such bias, categorical information (animate vs. inanimate; faces vs. bodies; and others) was mostly equivalent between the two modalities. Fusion with fMRI also revealed comparable spatiotemporal dynamics for MEG and EEG. However, investigation of V1 and IT revealed unexpected results: while the two modalities equivalently matched fMRI data in V1, MEG was more similar to fMRI in IT than EEG, despite the increased sensitivity of EEG to late components. Overall, we found EEG and MEG were sensitive to partly common and partly unique aspects of visual representations. Together, our results offer a novel comparison of MEG and EEG signals in representational space, and motivate the wider adoption of multivariate analysis methods in both MEG and EEG.

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33.4025 Number in the human subcortex

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Certain numerical abilities appear to be relatively ubiquitous in the animal kingdom, including the ability to recognize and differentiate relative quantities. This skill is present in human adults and children, as well as in non-human primates. Perhaps surprisingly, numerosity abilities are also demonstrated by lower species such as mosquito fish and spiders, despite the absence of cortical computation available to primates. This ubiquity of numerical competence suggests that representations that connect to numerical tasks are likely subserved by evolutionarily conserved regions of the nervous system. Here, we test the hypothesis that the visual evaluation of relative numerical quantities is subserved by lower-order brain structures in humans. We use a paradigm (Wheatstone stereoscope) that permits presentation of a stimulus to a single eye and compare discrimination performance when targets are shown monocularly versus dichoptically. Across multiple experiments, we show that the discrimination of displays, consisting of both large (5-80) and small (1-4) numbers of dots, is facilitated in the monocular, subcortical portions of the visual system. This is only the case, however, when observers evaluate larger ratios of 3:1 or 4:1, but not smaller ratios, closer to 1:1. Additional analyses evaluating which of 9 continuous stimulus parameters (such as size, spacing, coverage, etc.) explained participants' performance revealed that number best accounted for behavior and did so with an effect size an order of magnitude larger than any other parameter. This profile of competence matches closely the skill with which newborn infants and other species can discriminate numerical quantity. These findings suggest conservation of ontogenetically and phylogenetically lower-order systems in adults' numerical abilities. The involvement of subcortical structures in representing numerical quantities provokes a reconsideration of current theories of the neural basis of numerical cognition, in as much as it bolsters the cross-species continuity of the biological system for numerical abilities.

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33.4026 A case of severe impairments in mid-level vision but intact face recognition, biological motion processing and reading abilities

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The general notion of visual development is that basic visual functions develop before more complex ones. Here, we report a developmental case that seems to contradict this notion: LS, a 26 y.o. woman, shows severe impairments in mid-level, but intact higher-level vision. LS was first investigated in 2006 (age 16) due to difficulties in mathematics: Anamnesis revealed no previous illnesses/incidents that might have caused problems in visual abilities, but testing showed severe impairments in line and form discrimination. Since April 2016 we have the opportunity to re-assess LS: She has obtained her driver's license at age 18 and is driving since then, has finished high-school and is in vocational training. Visual acuity is in the normal range when measured with numbers or letters, but impossible to test with Landolt-C or Lea-Symbols. Color vision is normal. LS is able to process form-from-motion when it is biological, e.g. point-light-stick-figures, but not with simple forms. LS failed the screening test of the VOSP and showed deficits in five of the eight subtests, while she performed normally on incomplete letters, dot counting and position discrimination. She is fast and accurate in naming letters as well as line-drawings of common objects in the BORB, but markedly slowed with two overlapping items, and unable to perform the task with three. LS shows peculiar eye movements, consummately tracing lines and outer contours with her gaze, or using her fingers with 3D-objects. LS shows normal to above average performance on the Benton and the CFMT. She performed both tests swiftly and without hesitation. LS is aware of her visual "peculiarities" and her "tracking strategy". LS's visual profile seems to suggest dissociations in the development of mid-level and higher-level visual functions, which we will be testing further—both behaviorally as well as through neuroimaging—in the upcoming months.

33.4027 Self-reported visual perceptual abnormalities predict schizophrenia, poor premorbid functioning, and more severe positive symptoms: New Insights from the Bonn Scale

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Background & Methods. Past studies using the Bonn Scale for Assessment of Basic Symptoms have shown that self-reported visual perceptual abnormalities (VPAs) predict which individuals convert to schizophrenia (Klosterkötter et al., 2001). To further consider the clinical value of VPAs and the Bonn Scale, we employed the instrument to assess lifetime occurrence of VPAs within 22 chronic schizophrenia/schizoaffective disorder patients and 21 first episode psychosis patients, and probed for potential

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relationships with illness duration, diagnosis, age of onset, symptom severity, and premorbid functioning. Corrections for multiple comparisons were implemented with the False Discovery Rate controlling procedure (Benjamini & Hochberg, 1995). Results. VPA frequency was similar between the chronic and first episode groups, and was uncorrelated with illness duration (ps>.45). Subjects with schizophrenia/schizoaffective diagnoses (SZ/SA; n=31) endorsed more VPAs compared to those with other less severe psychotic disorders (n=12; p=.04; d=0.79). Specifically, the SZ/SA group more frequently reported double/reversed vision and abnormal perception of color, faces, body parts, and object movement (ps< .05; ds>.65). Increased overall VPAs predicted more hallucinations, delusions, and bizarre behavior (ps< .001; rs>.57) but not negative, disorganized, excited, or depressed symptoms (rs< .34; ps>.05). Increased VPAs correlated with earlier age of onset, worse sociability and ability to adapt in school, and lower ability to function well during childhood and early adolescence (ps< .05; rs>.39). Conclusion. VPAs, as assessed with 17 simple yes/no questions from the Bonn Scale, are strongly linked to positive symptoms, premorbid functioning, and a schizophrenia/schizoaffective disorder diagnosis. Surprisingly, the full gamut of abnormal visual perceptual experiences will have already been experienced by the time a person reaches the first psychotic episode. These results underscore the relevance of VPAs and the Bonn Scale for understanding schizophrenia; they also highlight the need for vision researchers to document and explain the visual perceptual changes that accompany the disorder.

Acknowledgement: K01MH108783

33.4028 **Neuronal correlates of rapid learning in the human medial temporal lobe** Jiye Kim[1], Julie Blumberg[2], Franz Aiple[3], Peter Reinacher[4], Jed Singer[1], Armin Brandt[3], Andres Schulze-Bonhage[3], Gabriel Kreiman[1]; [1]Boston Children's Hospital, Harvard Medical School, [2]Department of Neuropediatrics and Muscle Disorders, Medical Center, Faculty of Medicine, University of Freiburg, Germany, [3]Department of Neurosurgery, Medical Center, Faculty of Medicine, University of Freiburg, Germany, [4]Department of Stereotactic and Functional Neurosurgery, Medical Center, Faculty of Medicine, University of Freiburg, Germany

One of the greatest feats in human cognition is the ability to rapidly acquire new information. A prominent example of this ability is manifested during learning to identify new objects, even after single trial exposures. The neural mechanisms subserving this behavior, however, are largely unknown. Here, we studied neuronal responses to instances of single shot learning using Mooney images. Mooney images render objects in binary black and white in such a way that they can be very difficult to recognize. After exposure to the corresponding grayscale image, it becomes easier to recognize the objects in the original Mooney image. We recorded single unit responses in the human brain, mostly from the medial temporal lobe, from 13 epilepsy patients implanted with electrodes for clinical purposes. The experiment began with presentation of Mooney images. Subjects learned the identity of these initially unrecognized Mooney images via paired viewing of their grayscale counterparts. Finally, the Mooney images were presented again alone. We compared the neuronal responses of 1118 unit clusters in response to three main conditions: (i) Mooney images that were not recognized (preGS), (ii) identical Mooney images that were recognized (postGS) and (iii) corresponding grayscale images (GS). About 20% of them showed significant modulation of firing rates in the 0-500 ms interval after stimulus onset across conditions. Of those units, 12% showed firing rate modulation dependent on changes in recognition with similar responses to postGS and GS and different responses to preGS and postGS. Additionally, 32% of those units showed similar responses to preGS and postGS and different responses to GS and postGS. These results demonstrate a single unit signature of rapid learning in the human medial temporal lobe and provide initial steps to understand the mechanisms by which top-down inputs can rapidly orchestrate plastic changes in neuronal circuitry.

Acknowledgement: National Science Foundation

Perceptual Learning: Plasticity and adaptation

Sunday, May 21, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.4029 **Single exposure effects on a perceptual task** Tyler Barnes-Diana[1](tyler_barnes-diana@brown.edu), Takeo Watanabe[1], Yuka Sasaki[1]; [1]Brown University

It is well-known that stimulus exposure influences the perception and performance on a subsequently presented stimulus. Despite this, it is unclear whether such pre-training exposures have a longer-lasting effect or whether they influence perceptual learning. To address these questions, we investigated the effect of pre-training exposure on subsequent training over a multiple sessions across days on a perceptual task. Two groups of subjects (n=22, n1 = n2 = 11) were first exposed to a single 100-ms stimulus. One group to a peripheral noise patch, and the other group to a peripheral vertical orientation. The procedure of training was identical for both groups and consisted of 8 blocks of 100 trials for one session, with a total of two sessions, one on each of two consecutive days. On each trial subjects reported on a central letter detection task (T or L) and a peripheral coarse orientation discrimination task (tilted left or right from vertical). Both groups received an identical central letter. Despite a manipulation only on the peripheral stimulus our results showed longer reaction times and higher accuracy on the central letter detection task in the group that received a vertical reference compared with the group that received a noise patch. There was no significant difference between groups on peripheral performance measures and no interactions were found across days. These results indicate that a single brief exposure to a stimulus has a significant and lasting effect on subsequent perceptual responses. These results not only underscore the importance of careful control and further investigation of common features of pre-training procedures, but shows a strong effect of a brief single stimulus on subsequent task performance.

Acknowledgement: NIH R01EY019466, Center for Vision Research T32EY018080

33.4030 **Contrast adaptation reduces SSVEP amplitude** Mark Vergeer[1](mvergeer@umn.edu), Juraj Mesik[1], Yihwa Baek[1], Kelton Wilmerding[1], Stephen Engel[1]; [1]Department of Psychology, College of Liberal Arts, University of Minnesota

Contrast adaptation can dramatically alter neural response to the adapted orientation. However, measuring adaptation with EEG has proven challenging, as the large number of test presentations required can reduce the effects of adaptation. Here, we measured changes in neural response due to adaptation using steady-state evoked potentials (SSVEP) and a frequency tagging technique. Stimuli were presented on a head-mounted display and EEG signals were recorded using a dry electrode system. The test stimulus was a plaid consisting of horizontal and vertical gratings that reversed their contrast at different frequencies (6 and 15 Hz, respectively). A pilot experiment showed that increasing the contrast of the vertical grating in the test plaid, with the contrast of the horizontal grating fixed, produced a monotonic increase in occipital 15 Hz SSVEP amplitude. Next, eight volunteers performed the main experiment, in which they adapted to full-contrast vertical gratings, contrast reversing at 15 Hz. During each 1.5 sec trial, the test plaid was presented with 5% vertical contrast and 25% horizontal contrast. Trials were presented in blocks that began with 30 seconds of adaptation, and each trial was preceded by 6 seconds of "top-up" adaptation. A baseline recording session, preceding the adaptation session was identical, except it lacked presentation of the adapting gratings. Adaptation to vertical significantly reduced occipital response to the adapted orientation; amplitude of the 15 Hz response decreased by 62% from baseline, $p < 0.05$. Effects were orientation specific; response to the 6 Hz horizontal grating increased non-significantly in amplitude following adaptation, and the ratio of the two responses (15 Hz / 6 Hz) decreased significantly following adaptation (by 60%, $p < 0.05$). In demonstrating that contrast adaptation leads to a strong reduction in SSVEP response, these results highlight the potential of SSVEPs to powerfully address questions of visual plasticity.

Acknowledgement: NSF BCS1558308

33.4031 **Role of exogenous attention in task-relevant perceptual learning** Kieu Nguyen[1](knguy044@ucr.edu), Takeo Watanabe[2], George Andersen[1]; [1]University of California, Riverside, [2]Brown University

Sunday AM

Repeated exposure on a visual perceptual task renders performance improvements on that task known as perceptual learning (PL). However, no current consensus exists with regard to whether features of PL are specific or generalizable, the brain locus of PL, and the mechanisms underlying task-relevant PL (TR-PL). However, a recent theory posits that PL may actually occur in different stages revealing two types of learning plasticity and may actually encompass discrepant PL findings (Shibata, Sagi & Watanabe, 2014). To experimentally dissociate these two types of learning, the type of attention must be considered as the type of attention has been shown to differentially modulate perceptual processes. Using this framework, the current study investigates the role of exogenous attention using oriented gabor patches embedded in white Gaussian noise in a 2-alternative forced choice TR-PL task. We did a between-groups manipulation of exogenous attention by manipulating effectiveness of the attentional cue during training (cue validity); 100% valid, 50% valid, neutral cue, and no cue. Pre- and post- training noise thresholds of trained and untrained orientation were obtained. It was found that training with attentional cues facilitated PL with greater improvement for 100% valid cue condition as compared to no cue condition for trained orientations but not for untrained, suggesting that learning may occur in lower-level visual processing. Although learning was found based on validity of the cue, there was no difference between groups after training. Our findings suggest that manipulation of exogenous attention modifies PL at lower levels of visual processing in the cortex.

33.4032 **Monocular deprivation of Fourier phase information boosts the deprived eye's dominance during interocular competition but not interocular phase combination** Min Bao[1,2](baom@psych.ac.cn), Jianying Bai[1], Xue Dong[1], Sheng He[2,3]; [1]Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, [2]State Key Laboratory of Brain and Cognitive Sciences, [3]Department of Psychology, University of Minnesota

Ocular dominance has been extensively studied, often with the goal to understand neuroplasticity, which is a key characteristic within the critical period. Recent work on monocular deprivation, however, demonstrates residual neuroplasticity in the adult visual cortex. After deprivation of patterned inputs by monocular patching, the patched eye becomes more dominant. Since patching blocks both the Fourier amplitude and phase information of the input image, it remains unclear whether deprivation of the Fourier phase information alone is able to reshape eye dominance. One way to answer this question is to test whether the eye dominance shifts or not after one eye is deprived of the phase-aligned frequencies describing contours and higher level spatial representations, on the premise that the Fourier amplitude spectra of the visual inputs remain identical across the two eyes. Here, for the first time, we show that removing of the phase regularity without changing the amplitude spectra of the input image induced a shift of eye dominance towards the deprived eye, but only if the eye dominance was measured with a binocular rivalry task rather than an interocular phase combination task. These different results indicate that the two measurements are supported by different mechanisms. Phase integration requires the fusion of monocular images. The fused percept highly relies on the weights of the phase-sensitive monocular neurons that respond to the two monocular images. However, binocular rivalry reflects the result of direct interocular competition that strongly weights the contour information transmitted along each monocular pathway. Monocular phase deprivation may not change the weights in the integration (fusion) mechanism much, but alters the balance in the rivalry (competition) mechanism. Our work suggests that ocular dominance plasticity may occur at different stages of visual processing, and that homeostatic compensation also occurs for the lack of phase regularity in natural scenes.

33.4033 **Reduction in adaptation is necessary for perceptual learning to occur** Kazuhisa Shibata[1,2](kazuhisa_shibata@brown.edu), Ariel Choi[1], Yuka Sasaki[1], Takeo Watanabe[1]; [1]Department of Cognitive, Linguistics, & Psychological Sciences, Brown University, [2]Department of Psychology, Graduate School of Environmental Studies, Nagoya University

Repetitive exposure to a visual feature results in two opposite behavioral consequences: performance deterioration (PD) due to visual adaptation and increased performance on the feature, namely, visual perceptual learning (VPL). Whether visual adaptation relates to VPL formation process has been a long-standing controversial issue. To resolve the controversy, we measured both PD and VPL on an orientation detection task during training. The experiment consisted of 1-day pre-test, 5-day training, and 1-day post-test stages. One group of subjects (N=7) was presented with stimuli only in the non-dominant eye while the other group (N=6) in the dominant eye. For the non-dominant eye group, during daily training, the mean performance decreased, indicating that PD occurred on each day. The degree of PD decreased with increasing training days. In contrast, performance at the post-test stage was significantly higher than during the pre-test stage, indicating that VPL occurred after the 5-day training. Importantly, the degree of reduction in PD over the 5 days of training was significantly and highly correlated with the degree of VPL across subjects. On the other hand, for the dominant-eye group, neither significant reduction in PD during daily training nor VPL occurred. Since early performances on each day were almost constant in both groups, it is unlikely that a daily performance gain due to VPL occurred. Thus, the significant correlation between the PD reduction and VPL in the non-dominant group cannot be explained by the hypothesis VPL causes larger reduction in PD. These results are rather consistent with the hypothesis that PD reduction is necessary for VPL to occur. To our knowledge, these are the first results that show the causal relationship between PD and VPL.

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33.4034 **Perceptual effects of adaptation over multiple timescales** Nikos Gekas[1](nikos.gekas@outlook.com), Kyle McDermott[2], Pascal Mamassian[1]; [1]Laboratoire des Systèmes Perceptifs, CNRS UMR 8248, Département d'Études Cognitives, École Normale Supérieure, Paris, France, [2]Vizzario, Inc, USA

It is well known that adaptation to a visual stimulus leads to a negative correlation between the current percept and previous percepts. However, there are diverging views on how stimuli further in the past affect the current percept. We have argued that the negative correlation between the current percept and recent ones is accompanied by a positive correlation with events occurring further in the past (Chopin and Mamassian, Current Biology, 2012; McDermott et al., VSS, 2015). Here, we design a novel psychophysical experiment to measure the perceptual effects of adapting to dynamically changing stimulus statistics. Observers are presented with a series of oriented Gabor patches from a range of orientations and are asked to judge whether the orientation of some test patches in the series is clockwise or counter-clockwise from a reference orientation. Unbeknownst to the observers, the test stimuli are always at the point of subjective equality as measured at the start of the experiment, i.e. they are highly ambiguous. The orientations of the stimuli before each response are drawn from a Gaussian distribution whose mean changes slowly in time following a sinusoidal pattern. Moreover, the frequency of the sine wave increases as the experiment progresses, thus affecting the rate of mean orientation change. We measure the bias in observers' responses over the course of thousands of trials and hundreds of responses. Our results suggest that a negative tilt after-effect for short timescales gradually changes into a positive effect for trials further in the past. In addition, there is a weak positive correlation with stimuli seen hundreds of trials before the current percept. We present a computational model that illustrates how a combination of negative and positive correlations can predict the psychophysical data more accurately that a single negative correlation with recent stimuli.

33.4035 **Perceptual learning of spatial frequency identification through learned reweighting.** Barbara Dosher[1](bdosher@uci.edu), Jiajuan Liu[1], Zhong-Lin Lu[2]; [1]Cognitive Sciences, University of California, Irvine, CA , [2]Psychology, The Ohio State University

The detection and discrimination of patterns are thought to reflect the selectivity and distribution of spatial frequency (and orientation) channels in early vision (Campbell et al., 1970). Spatial frequency discrimination (frequency differences) has historically been examined in two-alternative tasks in which a test stimulus is of either higher or lower spatial frequency than a standard. Perceptual learning has been documented in many tasks (Fine & Jacobs, 2002), and in some tasks the learning was specific to spatial frequency. However, perceptual learning of spatial frequency judgments themselves has not been extensively studied, although perceptual learning of the discrimination of contrast or phase differences in one component of a compound stimulus has been studied (e.g., Fiorentini & Berardi, 1981). The current study examines perceptual learning in identification of eight

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stimuli that differ in spatial frequency (8AFC), in half-octave intervals with 8 center frequencies from 0.48 to 5.41 cpd, embedded in external noise, and presented briefly at one of two pre-cued peripheral locations. Contrast thresholds were measured at 54% correct using adaptive methods in 8 sessions of 800 trials each. Some observers learned in this challenging task, showing improved accuracy in the confusion matrices and/or improved contrast thresholds over the course of learning. Other observers showed little learning. Qualitative properties of the performance are related to predictions of an elaboration of the Integrated Reweighting Theory (IRT, Dosher et al., 2013) for nAFC tasks using multiple decision units and a max rule for decision.

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33.4036 The time course of adaptation to changes in environmental orientation statistics Patrick Shafto[1](patrick.shafto@gmail.com), April Schweinhart[1], Ed Essock[2], Lewis Baker[1], Deepak Jonnalagedda[1]; [1]Rutgers University - Newark, [2]University of Louisville

It has been argued that natural scene statistics influence perception of structure in naturalistic environments. Specifically, the distribution of oriented content in the environment inversely matches the perception of broadband, orientated structure (e.g., Essock, et al., Vis. Res., 2003; Essock, Haun, & Kim, JOV, 2009). We have previously shown that adapting observers to an environment with atypical content can reliably change perception of structure after only two hours of experience (Schweinhart, Shafto, & Essock, in press). Specifically, observers' visual perception changed in ways that are predicted by a Bayesian model that assumes adaptation to the statistical content of the new environment (Girshick, Landy, & Simoncelli, Nat. Neuro., 2011). Here, we investigated the time course of adaptation to a horizontally-decremented environment. We modified the distribution of amplitudes of visual orientations that subjects encountered via FFT filtering of their environment in near-real-time. The duration during which the subjects experienced the filtered environment was varied from 5 to 240 minutes. Analysis revealed a plateau in the strength of adaptation effects as adaptation duration increased consistent with previous research showing that adaptation effects are best fit by a power function (Dong, Engel, & Bao, Perception, 2014; Hakk, et.al., Curr, Bio ., 2014). By weighting the contribution to the prior of the typical environmental distribution and that of the newly experienced distribution, we were able to effectively model the change in observers' orientation perception across different durations of adaptation in an atypical environment.

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33.4037 Structured knowledge and novel object kinds can be inferred from visual event streams Anna Leshinskaya[1](alesh@sas.upenn.edu), Sharon Thompson-Schill[1]; [1]Center for Cognitive Neuroscience, University of Pennsylvania

Experience unfolds as a stream of particular sensory events. Yet from such unstructured and specific input, humans are able to build structured and generalizable representations such as algebraic rules (Marcus, G. F., Vijayan, S., Rao, B., & Vishton, P. (1999). Rule learning by seven-month-old infants. Science, 283(Jan), 77–80). In Experiment 1, we probed several properties of learning in a similar scenario, in which participants viewed continuous streams of events with no instruction to find regularities. Events were visual changes of state (e.g., flashes of light, streams of bubbles), with weaker or stronger pairwise transition probabilities. We asked whether learners would be sensitive to directionality differences among pairwise relationships (AB vs BA), and, additionally, whether they would see such asymmetrical predictive relations as causal. We saw evidence of directionality sensitivity using a 2AFC task ($t(18) = 4.26$, $p < 0.001$). Subjects who were accurately aware of the predictive relationships also attributed causality to them when probed post-task ($t(10) = 3.13$, $p = 0.01$). This supports the idea that spontaneous sensitivity to event statistics can lead to the acquisition of structured and even causal representations without instruction to look for them. In Experiment 2, we investigated whether such event statistics could be used to construct novel categories of objects. Events took place surrounding different novel objects, which sometimes moved. In the presence of each object, event statistics could vary: either their movements followed, or preceded, another of the events (e.g., light flash); movements were unrelated to other, equally frequent events. Thus, objects differed purely on the direction of statistical contingency to a certain event. Participants reliably classified another new object according to this event structure, controlling for physical shape (Binomial test, $p = 0.005$). We suggest that sensitivity to such event statistics can support the acquisition of functional categories of objects.

33.4038 Behaviorally relevant prior experience biases subsequent perception Helen Feigin[1](helen.feigin@gmail.com), Shira Baror[1], Moshe Bar[1], Adam Zaidel[1]; [1]Gonda Multidisciplinary Brain Research Center, Bar-Ilan University

Background: Perception is flexible, and influenced by prior experience. However, the mechanisms underlying the effects of experience on subsequent perception are yet unclear. Here we investigated the influence of behavioral relevance of the prior experience on biasing subsequent perception, and examined the extent to which these influences are mediated by high-level decisions vs. low-level sensory or motor involvement. Method: A series of visual stimuli (uniformly filled circles) were presented on a screen. Participants judged whether each "target" circle was to the left or right of the screen's center (2AFC via button press). Each target circle was preceded by several "prior" circles with randomly distributed locations, which were either (on average) centered or biased to the left/right of the screen center. To dissociate behavioral relevance and motor responses, different task conditions were applied: i) prior circles' task was the same as for the target circles, ii) motor responses were inhibited for prior circles, iii) prior circle judgments were reported via different buttons, or prior circle color (and not location) was judged, such that (iv) motor responses alone were biased, (v) or stimulus locations were biased, but not explicitly judged (behaviorally irrelevant). Subjective perceived center was assessed for each condition. Results: Subjective perceived center shifted after relevant judgments, but not when motor responses alone were biased, or when stimulus locations were biased without being explicitly judged. Importantly, perceptual bias (for relevant judgments) ensued even when motor responses were dissociated. Conclusion: Behavioral relevance has a key role in biasing future perception by prior experience; low-level sensory bias is not always enough to influence subsequent perception. However, if that same information is behaviorally relevant, it would lead to a strong perceptual bias. This effect is not mediated by motor repetition, and occurs without external feedback. Relationship to attention, top-down and bottom-up processing is discussed.

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33.4039 Adaptation Is Slower in High Variability Environments Feiyi Ouyang[1](ouyan103@umn.edu), Stephen Engel[1]; [1]Department of Psychology, University of Minnesota

Visual adaptation has traditionally been viewed as passive, but more recent models propose that it depends upon active inference of environmental change. To test this theory, we measured adaptation to environments that were more or less variable, under the assumption that variability will slow inference and hence adaptation. Apparent contrast of a vertical grating was measured following adaptation in high or low contrast conditions. Adapting gratings (1.5 cyc/deg, 5.4 deg) were presented for 4 sec on one side of fixation, and their contrast was updated every 200 msec from a distribution of contrasts. In low variance sessions, narrow uniform distributions centered on 0.1875 and 0.7125 were used for the low and high contrast conditions respectively. In high variance sessions, the distributions were the weighted sum of three narrow uniform distributions, centered on contrasts of 0.1, 0.45, and 0.8. For the low contrast condition, 0.1 was weighted highly, and the overall distribution mean was 0.1875. For the high contrast condition, 0.8 was weighted highly, and the overall distribution mean was 0.7125. The adapting sequence was followed by a test patch (1.5 cyc/deg, 4.5 deg, 25% contrast) presented along with a "match" patch on the unadapted side of fixation for 200 msec. Subjects judged which appeared higher contrast, and the match contrast was adjusted using a staircase procedure. 60 trial blocks with low contrast adapters alternated with blocks using high contrast adapters. For each block, adaptation rate was estimated by an exponential fit to the staircased match contrasts. The rate of adaptation when the adaptor changed from low to high contrast was slower for the high variance session than the low variance session ($p < 0.01$). This suggests that adaptation is slower when environmental changes are more difficult to detect, consistent with adaptation being controlled by an inference process.

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Sunday AM

33.4040 Discriminability of Prediction Artifacts in a Head-Mounted Display

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1 Introduction Latency mitigation remains a fundamental issue in head-tracked virtual reality systems. Although predictive compensation can reduce perceived latency, other visual artifacts may appear due to improper calibration. The present study examines the discriminability of these prediction artifacts during active head rotation in a two-alternative forced-choice detection task. 2 Method A virtual environment (VE) was rendered through a custom graphics engine and displayed using an HTC Vive virtual reality headset. Predictive compensation was manipulated to overshoot (display lag) or undershoot (display lead) the estimated end-to-end latency by up to 80 milliseconds, leading to concomitant changes in image stability. Participants yawed their heads back-and-forth in time with a metronome and were asked to judge whether sequentially presented VE conditions were perceptually equal in terms of image stability. Overshoot and undershoot trials were presented in random order across two interleaved staircases following a three-down, one-up adaptive procedure. 3 Results Psychometric estimates for the point of subjective equality (PSE) and just noticeable difference (JND) were computed based on results from five subjects. Psychophysical estimates for the absolute threshold, PSE, and JND were consistent with previous findings, but showed greater sensitivity for undershoot trials compared to overshoot trials. 4 Conclusion In general participants were most sensitive to prediction artifacts that manifested in terms of display lead. These findings are among the first to explicitly compare the effects of display lead and display lag on judgments of perceptual stability in a wide field of view virtual reality head-mounted display.

33.4041 The effect of perceptual learning on reducing sensory eye dominance

Eunbin Lee[1](eunbin.lee43@gmail.com), Sang Chul Chong[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

People with large sensory eye dominance (SED) tend to perform worse in tasks requiring binocular vision because of their unbalanced interocular inhibition. The current study aimed to reduce SED by combining two perceptual learning techniques—the mean orientation discrimination (MOD) task (Mansouri et al., 2004) and a push-pull perceptual learning protocol (Xu et al., 2010). In the MOD task, half of 16 oriented Gabors were presented within a donut frame to each eye simultaneously and participants judged their mean orientation. The contrast of Gabors shown to the weak eye was increased according to participant's latest SED measurements, and task difficulty was increased when performance reached over 90% accuracy. In the push-pull protocol, a brief clockwise movement of the frame shown to the weak eye induced participant's attention. Ten participants were assigned to each of three groups: basic training, combined training, and control. The basic training used the MOD task, and the combined training used the MOD task together with the push-pull protocol. There were 16 sessions including 4 SED measurements and 12 trainings. SED was measured before and after every 4th training session. For the control group, we measured participants' SED four times without any training and the interval between each measurement was closely matched to the two groups. We found that the SED was significantly reduced in the two training groups, but not in the control group, indicative of positive training effects. However, the training effects did not differ between the two training groups. In addition, as the first measured SED was larger, the training effects became larger, which was mediated by the increased difficulty of the MOD task during the training. Overall, our results suggest that SED can be reduced by both the MOD task and the push-pull protocol.

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33.4042 Short-term patching does not affect interocular correlation sensitivity

Jacob Sheynin[1](jacob.sheynin@mail.mcgill.ca), Alexandre Reynaud[1], Robert Hess[1]; [1]McGill Vision Research, McGill, Dept. Ophthalmology, McGill University, PQ, Canada

Binocular vision and subsequently global stereopsis results from the integration of two similar but not identical retinal images. As such, sensitivity to interocular correlation is a necessary precursor to global stereopsis. Short-term (150 mins) monocular deprivation has been shown to both enhance the contribution of the occluded eye to binocular combination and to improving stereoacuity (Ng and Farrell, 2016). In the present study, we adapted the quick Contrast Sensitivity Function (qCSF, Lesmes et al., 2010) to the quick Correlation Sensitivity Function (qCorrSF) to examine the effect of patching on the discrimination of interocular correlation. The stimuli used to measure interocular correlation consisted of two dichoptic noise patterns modulated by a sinusoidal oblique envelope of correlation structure (45° or 135° degrees). At the peak of the sinusoid, the two patterns were maximally correlated and at the trough they were minimally correlated. We compared subjects' baseline qCorrSF to their performance after 150 minutes of monocular deprivation with a diffuser eye-patch, and took an additional measure at 30 minutes after patching. Our study took place over the course of three separate days. Across these sessions, we counterbalanced the order in which we either patched subjects' dominant or non-dominant eye, or conducted a control session where no eye was patched. Our preliminary results have not indicated a consistent effect of patching on subjects' correlation sensitivity function. While patching has been shown to improve stereoacuity, our results indicate that this effect may not be attributed to an enhanced sensitivity to interocular correlation. Acknowledgements ERA-NET NEURON Grant (JTC 2015) to RFH

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33.4043 Rapid compensation for defocus in the myopic visual system

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When the environment changes, the visual system automatically adjusts its function in order to maintain appropriate behavior. It is unknown, however, to what extent such adaptation effects can be modified by experience. We investigated adaptation to the optical defocus that arises when observers remove their spectacles. We tested whether myopic observers have learned to rapidly compensate for this image blur, which will reduce the retinal contrast of small image features. We compared the myopic observers to ones with normal vision (emmetropes) presented with comparable defocus through blurring lenses. Participants judged the intensity of a small (0.25 deg), dark (5.89 cd/m^2), circle presented on a gray (32.9 cd/m^2) background in an image of an outdoor scene. The small circle was presented for 500 msec following a 500 msec presentation of a large (1 deg) circle, and subjects judged which appeared lighter. The large circle, less affected by blur, was adjusted using a staircase procedure to estimate the apparent luminance of the small circle. For myopic observers (n = 9, mean prescription -2.0D +/- 0.2D), the small circle appeared almost identical in luminance without their glasses as with them (difference was 0.27 cd/m^2, n.s). For emmetropes (n = 8) comparable blur, created by donning +2.0D spectacles, made the circle appear substantially lighter (by 2.09 cd/m^2, $p < 0.03$). The difference between groups was reliable, $t(14) = 2.22$, $p < 0.05$, and arose within a few seconds of exposure to blur. The visual acuity of myopic observers, assessed with a standard eye chart, was also less affected by the blur (0.48 logMAR vs 0.82 logMAR for emmetropes, $t(14) = 7.19$, $p < 0.01$). Our results suggest that myopic observers have learned to rapidly compensate for the blur that results when they view the world without correction.

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33.4044 Evidence of disinhibition as a mechanism for short-term plasticity following a simulated peripheral scotoma

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Following loss of visual input, deafferented visual cortex remaps to represent visual space outside of its classical retinotopic boundaries. Long-term and enduring reorganization of this kind is proposed to occur through changes in the functional balance within visual circuits, which begin the process of producing long-lasting changes. Within seconds of deafferentation, measureable changes in the functional balance within visual circuits begin through a mechanism of disinhibition. In this study, we investigated these short-term changes that occur within deafferented human visual cortex during a simulated retinal scotoma (artificial scotoma) paradigm by recording electroencephalogram (EEG) while participants performed a stimulus discrimination task. Participants were conditioned with an artificial scotoma positioned 8.0° in the periphery for 6 seconds prior to a sinusoidal visual probe briefly flashing either within the boundaries of the scotoma or in two extra-scotoma locations. Visual evoked potentials (VEPs) evoked by the onset of these visual probes were used to examine changes in cortical excitability within and outside of the cortical representations of the scotoma region. The orientation of the stimulus probes were also manipulated to be one of five tilts: 0.3°, 0.6°, 1.2°, 3.4°, and 8.0° so that psychophysical orientation functions of stimulus selectivity within the scotoma region could be examined. Our results indicate an increased amplitude in the early-phase P1 component of the VEP, as well as a reduction in the slope of the psychophysical orientation function, for visual probes within the scotoma region. The potentiated early cortical response and broader tuning within the scotoma region are consistent with models of disinhibition as a mechanism of neuroplasticity and topographical reorganization within the human visual system.

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33.4045 **Rapid development of reaching/grasping and intersensory recognition in a previously blind Tibetan girl** Frank Thorn[1,2](thornf@neco.edu), Jie Chen[1], En-De Wu[1], Xin Chen[1], Lu-He Zhu[1], Xiaoman Li[1], Jia Qu[1]; [1]Wenzhou Medical University, School of Optometryand Ophthalmology and Eye Hospital,, [2]Department of Vision Science, New England College of Optometry

On a charity mission we discovered a 44 month-old Tibetan girl who was blind due to dense bilateral congenital cataracts. We report here the results of video-recorded experiments on the child immediately after post cataract surgery eye patch removal: looking and reaching/ grasping responses during the first hour and crossmodal object recognition during the next 5 days. These tasks all involve different aspects of linking visual and tactile sensory information together. At first sight, she looks aimlessly around, at 5 min she discovers her hand, next she starts looking at objects in front of her, at 12 minutes she starts reaching and grasping for objects and by 24 minutes she does this with good accuracy. She has continuously recalibrated her movements using sensory feedback signals until she could accurately reach for and grasp objects. The next day we tested object recognition with single vs a triple length LEGO blocks. First, a block was placed in her hand for her to see and feel simultaneously. Then in a paired comparison she chose by vision alone the correct LEGO almost perfectly. If she only saw a LEGO and then chose by sight or touched a LEGO and then chose by either touch or sight alone, she performed at chance. On the following day she recognized the correct LEGO in all three procedures. With a more difficult comparison (double vs triple LEGO) she was above chance (90%) with sight-to-sight but at chance with the other two comparisons. On day 5, she performed perfectly on sight-to-sight and the intermodal touch-to-sight with touch-to-touch still at chance. Recognition performance was the same when comparing a cube vs same size cylinder. These data indicate that the visual system is preprogrammed to quickly learn to visually recognize objects even if they were only touched initially.

Perceptual Learning: Specificity and transfer

Sunday, May 21, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.4046 **Visuomotor adaptation of walking and pointing: evidence for function-specific and motor-specific components** Xing Xing[1](xingxing@hku.hk), Jeffrey Saunders[1]; [1]Department of Psychology, University of Hong Kong

Sensorimotor recalibration in response to discrepant visual feedback occurs for goal-directed tasks like walking and pointing, and generalization across tasks can be used to infer the locus of adaptation. In this study, we distinguish two potential factors in generalization: the functional type of control task (locomotion vs pointing) and the specific limbs and movements that execute the actions (legs vs arm). To distinguish functional and motor specificity, we created a hand locomotion task: subjects used pointing movements to simulate self-motion in virtual reality. Experiment 1 first tested whether adaptation of walking direction generalizes to pointing, using a sinusoidal perturbation method (Hudson & Landy, 2012). Subjects walked toward a target in virtual reality and the mapping from physical to visual heading was varied over time. Interspersed with walking, subjects pointing toward targets without feedback to test generalization. Walking direction showed a damped and delayed response to the perturbations, but this adaptation did not generalize to pointing, consistent with previous studies using virtual reality. Experiment 2 tested generalization between hand locomotion and pointing using a similar method. Sinusoidal perturbations were applied to either the visual heading direction or the visual location of the hand, which produced adaptation, and generalization across tasks was measured with interspersed test trials. When self-motion was controlled by a pointing movement rather than walking, there was partial generalization from locomotion to pointing, and from pointing to locomotion. Experiment 3 tested generalization between hand locomotion and walking, and similarly observed partial generalization in both directions. Even though the tasks involved different limbs and motor actions, there was partial generalization between the two locomotion tasks. Our results demonstrate that visuomotor adaptation can generalize based on either shared functional task or shared motor actions. This suggests that adaptation involves both function-specific and motor-specific components.

33.4047 **Specificity in short- and long-term motor learning** Zili Liu[1](zili@psych.ucla.edu), Chéla Willey[1]; [1]Department of Psychology, University of California Los Angeles (UCLA)

Introduction. We tested the hypothesis that varied training, as compared to specific training, enhances motor learning. A well-known theory in learning, the schema theory, suggests that variation during practice enhances long-term learning, generalization, and retention. A particularly interesting prediction from this theory is that people who practice throwing alternately at two target distances (varied group) yield better learning and generalization than people who practice only at one target distance (specific group). This prediction was supported by results from Kerr and Booth (1978). Methods. We trained our varied group at 5 and 9 ft target distances, and our specific group at 7 ft. Participants threw a 9.05 oz. bean bag backward over their shoulders to one of the following targets: 3, 5, 7, 9, and 11 ft. These targets were marked on the floor for the participants to view at the beginning of each block. Participants either received or did not receive feedback after each throw. In our short-term study (n = 255), all pre-test, practice (120 trials), post-test 1, and post-test 2 were completed within an hour. In our long-term study (n = 30), the practice had 10 sessions (120 trials each) that lasted for approximately six weeks. We measured signed errors, absolute errors, and variances. Results. Only limited evidence of generalization was found as a result of varied training. One week after the long-term training at post-test 1, we found that the varied group better generalized to 11 ft than the specific group. However, this advantage ceased to be statistically reliable one week later at post-test 2. Conclusion. Overall, the learning could be characterized as generalizing locally to nearby distances (±2 ft), but not beyond, regardless of the training schedule or feedback. These results suggest similarities between motor learning and classic perceptual learning.

33.4048 **Learning induced illusions: Statistical regularities create false memories** Yu Luo[1](yuluo@psych.ubc.ca), Jiaying Zhao[1,2]; [1]Department of Psychology, University of British Columbia, [2]Institute for Resources, Environment and Sustainability, University of British Columbia

Although the visual system readily extracts regularities in terms of object co-occurrences over space and time, does learning such statistical relationships always result in the veridical representations of individual objects? Here we investigate an interesting consequence of statistical learning: how does the knowledge of statistical regularities alter the representations of individual objects which no longer co-occur with each other? During the exposure phase, observers viewed a continuous sequence of objects while performing a cover task to ensure incidental encoding of the regularities. Unbeknownst to the observers, the objects appeared either in pairs (e.g., A always appeared before B) in the structured condition, or in a random order in the random condition. In a subsequent recognition phase, a new continuous sequence of objects was presented, and observers judged whether a specific object was present in the sequence. Importantly, the sequence now only contained one member of the original pair (e.g., only A was presented and B was missing), and observers judged whether A or B was present in the sequence. We found that observers in the structured condition showed a reliably higher false alarm rate for the missing object (e.g., B) than in the

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random condition. At the same time, the hit rate for the presented object (e.g., A) in the structured condition was also higher than in the random condition. The results demonstrate that statistical learning not only sharpens the detection of the object within the regularities, but also induces a false memory of the missing object. This finding reveals a novel consequence of statistical learning: learning that two objects co-occur can create the illusion of seeing one object, even though only its partner is present.

33.4049 Ruling out task difficulty in the context-generalization of texture perceptual learning

Alicia Serrano[1](serrana@mcmaster.ca), Ali Hashemi[1], Allison Sekuler[1], Patrick Bennett[1]; [1]Department of Psychology, Neuroscience, & Behaviour, McMaster University

Perceptual learning in a texture identification task reflects improved sensitivity to diagnostic features. We have studied perceptual learning using orientation-filtered textures that contain identity-specific information in a horizontal orientation band (i.e., Target) and non-diagnostic information (i.e., Context) in a vertical orientation band. Using Target-alone or Target+-Context textures as training stimuli in a 1-of-6 texture identification task, Hashemi et al. (VSS 2015) demonstrated that learning was significantly more difficult in the Target+Context condition. Interestingly, the more difficult condition produced greater context generalization (Hashemi et al., VSS 2016): Target+Context trained observers generalized learning to the same Targets alone (i.e., presented without Context), but Target-alone trained observers did not transfer their overall strong learning to the same Targets with Context. These results may reflect a difference in perceptual strategies: Target-alone textures can be identified using any visible pixel, while Target+Context textures require observers to learn the selective extraction of target information in a specific orientation band and ignore the context. However, identifying Target+Context stimuli was significantly more difficult than Target-alone textures, so it is possible that the asymmetry in context generalization is a by-product of task difficulty and/or the magnitude of learning during training. Here, we tested that idea by adjusting stimulus contrast to make identification of Target-alone textures as difficult as Target+Context textures. We found that equating task difficulty did not eliminate the difference in context generalization: Target+-Context training improved identification of both Target+Context and Target-alone textures, but Target-alone training improved identification only of Target-alone textures. We conclude that context-generalizable learning reflects a perceptual strategy learned when observers have to distinguish diagnostic from non-diagnostic information, and is not simply a by-product of task difficulty.

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33.4050 The Effect of Cognitive Load on Visual Statistical Learning

Amir Tal[1](amir.tal@biu.ac.il), Shira Baror[1], Moshe Bar[1]; [1]The Leslie and Susan Gonda Multidisciplinary Brain Research Center, Bar-Ilan University, Ramat-Gan, Israel

In times of limited resources or stress, not only behavior changes, but modes of memory and learning change as well. Under cognitive load, learning is biased towards a habitual “model-free” mode, rather than a goal-directed and more flexible “model-based” one. However, it is not known how cognitive load affects the potency of model-free learning itself. Learning of statistical regularities embedded in the visual environment had been shown to act efficiently and automatically, in a model-free manner. In this study, the effect of cognitive load on visual statistical learning has been examined. Using a behavioral decision-making paradigm, subjects were presented with visual regularities either from experiment onset or from a later point in time, simulating learning in novel and familiar environments, respectively. Results indicate that cognitive load delays simple reinforcement learning of novel regularities, and diminishes the ability to learn new rules when familiar settings change. These indications suggest that albeit automatic and implicit, visual statistical learning depends on the availability of cognitive resources for its successful function.

33.4051 Perceptual learning based on the learning of diagnostic features

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We examined the idea that perceptual learning is driven by the learning of diagnostic features, which are generalized from the training stimuli. A visual search task was used, which required participants to detect the presence or absence of a “v”-shaped motion trajectory (dot moving down to the right and then up to the right), among distractor trajectories (dots moving up to the right and then down to the right). Over the course of ten training sessions, participants improved dramatically on this task, indicative of learning. After the end of training, we examined which feature(s) of the complex trajectory stimulus were learned during training. The most obvious assumption would be that participants learned the precise features and feature relationships underlying the motion trajectories that were trained. However, both stimuli contain identical horizontal motion cues and differ only in the temporal sequence of the vertical motion (down then up vs. up then down). Learning would be more efficient if it prioritized the diagnostic feature itself (i.e., the vertical motion sequence) in order to distinguish target and distractors. To explore this aspect, trained participants performed a control experiment for which the horizontal motion in the trajectories was entirely removed: the target moved vertically down and then up while the distractors moved up and then down. Results show that participants transferred their learning benefits to this condition even though it was missing part of the original trained motion pattern (the common horizontal motion). However, when the vertical component of the training motion was reduced by making the angle of the “v” and inverted “v”s wider, transfer to the purely vertical tests deteriorated. Overall, our results suggest that perceptual learning involves the independent learning of diagnostic features. As long as these diagnostic features remain intact, learning will generalize to other stimuli that contain them.

33.4052 Beyond classic Perceptual learning: Coordinated attentional training to boost learning and generalization

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Visual Perceptual Learning (VPL), improvements in visual tasks through experience, is an important tool for examining plasticity, and as treatment for diseases such as low vision. However, classic VPL presents some drawbacks, such as the high specificity (limited transfer of learning to beyond the training conditions) and the large number of training sessions needed to observe significant improvements. We suggest that key to overcoming these drawbacks is to implement training paradigms that are based on understanding of relevant models of neural processing and brain circuitry. A relevant case example where this approach can be informative and useful is Macular Degeneration (MD), where following central vision loss, patients must learn to use peripheral vision for everyday tasks that require fine-scale vision, such as reading, writing, and recognizing faces (Kwon, Nandy, Tjan, 2013). In MD, effective plasticity should entail not just optimization of low-level visual processes, as is the typical focus of VPL, but also higher-level vision and changes in top-down control of visual processing. A wide literature shows that top-down, attentional control in visual processing supports goal-directed behavior and involves interactions among fronto-parietal networks and early visual areas. Here, we focus on 2 well-studied networks. The “fronto-parietal” (FP) network, that includes the dorsolateral prefrontal cortex (dlPFC) and is involved in the moment-to-moment modulation of visual processing, and the ‘cingulo-opercular’ (CO) network that includes the dorsal anterior cingulate dACC and acts in part to maintain sustained attention. We present a novel coordinated attention training (CAT) designed to specifically target plasticity in how the FP and CO networks interact with visual cortex. We discuss how CAT training may produce more appropriate and generalizable learning than standard VPL frameworks that employ the same stimuli but with predictable central locations and timing and how this approach may be valid to other populations.

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33.4053 On learning two different tasks of same input stimulus

Qing He[1,2,3](heq@psych.ac.cn), Jiawei Zhou[4,5], Robert Hess[5], Chang-Bing Huang[1,3]; [1]CAS Key Laboratory of Behavioral Science, Institute of Psychology, CAS, Beijing, China, [2]University of Chinese Academy of Sciences, Beijing, China, [3]Visual Information Processing and Learning Lab (VisPal), Institute of Psychology, CAS, Beijing, China, [4]School of Ophthalmology and Optometry and Eye Hospital, Wenzhou Medical University, Wenzhou, Zhejiang, China, [5]McGill Vision Research Unit, Department of Ophthalmology, McGill University, Montréal, Québec, Canada

Characteristics of perceptual learning, particularly specificity or generalization, can be influenced by the taxonomic relationship between training and testing tasks and the performance level in the training and testing stages. To better illustrate these characteristics, we developed a set of global orientation/motion judgment tasks of identical stimulus, measured subject's performance at two tasks of twenty-five orientation/motion coherence intensities, and trained subjects to report either orientation or motion direction with the other untrained dimension (i.e. motion or orientation) at four different coherence levels. Four groups were trained on a global orientation discrimination task for eight days and the coherence levels of zero, threshold at 63% correct, threshold at 79%, and suprathreshold coherence were assigned to the task-irrelevant feature (i.e. global motion) in each group. Similarly, another four groups trained on a motion direction discrimination task and exposed to four different orientation coherence levels. We found that (1) subjects' thresholds for the trained task improved significantly, mostly around the trained performance level; (2) learning outcomes at the trained dimension were irrespective of the exposed level of untrained dimension; (3) training with exposure to a certain coherence level of untrained dimension can almost fully generalize to the same task but with different levels of untrained dimension; (4) no significant improvement in motion direction task was observed when subjects were trained on orientation discrimination task, no matter to which motion coherence level they were exposed; (5) For motion direction learning groups, the learning effect could significantly but only slightly generalize to orientation tasks, which is also independent of the exposed orientation coherence level. No significant gain in both tasks was found in the control group. Our results suggest that perceptual learning may not result from the strengthened representation at early stage but depends on the involvement of multiple cortical areas and complex neural networks.

33.4054 **Extensive training of orientation filtered textures increases generalization of learning** Ali Hashemi[1](hashea@mcmaster.ca), Allison Sekuler[1], Patrick Bennett[1]; [1]Department of Psychology, Neuroscience, & Behaviour, McMaster University

Previously, we (Hashemi et al., VSS 2015 & VSS 2016) investigated perceptual learning in a texture identification task using textures that contain diagnostic information (Target) in one orientation band and non-diagnostic information (Context) in a perpendicular orientation band. We found that, compared to Target-alone (i.e., no Context) textures, training in a 1-of-6 identification task with Target+Context textures resulted in lower accuracy, less learning, but greater generalization of learning. Specifically, training with Target+Context patterns generalized to familiar Target-alone textures, but training with Target-alone stimuli did not generalize to familiar Target+Context textures. Nevertheless, even with Target+Context training, we found no evidence of generalization to novel targets, regardless of context. Here we investigated whether greater generalization of learning could be obtained by significantly increasing the amount of training with Target+Context stimuli from 960 to 4200 trials. Before and after training, we assessed identification accuracy on trained and novel Targets with and without Context. We also tested accuracy on textures where the Target and Context orientations were swapped, using both novel and trained Targets. Results varied across observers: During training, accuracy increased by at least 50% in half of the participants, but only by ~20% in the others. Our post-training assessment found 1) all participants improved on the trained Target+Context textures; and some participants generalized learning to 2) familiar and novel Target-alone textures; 3) novel Target+Context textures; and/or 4) orientation-swapped Target+Context textures. Finally, the different patterns of generalization were not related in any simple way to the change in accuracy that occurred during training. Our results indicate that perceptual learning of orientation filtered textures varies significantly across individuals, but that it can be generalized to novel and familiar targets in novel contexts. These findings may have implications for perceptual learning in applied settings in which generalization of learning is a critical component of training.

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33.4055 **Cognitive bias and reward affect contrast and response gain** Parker Banks[1](banksp@mcmaster.ca), Allison Sekuler[1], Patrick Bennett[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Investigations of perceptual learning (PL) typically focus on stimulus and sensory factors that affect performance during training, and comparatively little is known about the roles response bias and reward structure play in determining how people learn from experience. Such questions are important because some naturalistic PL protocols (e.g., fingerprint identification) use extreme payoff structures that severely punish some responses. Therefore, we investigated how differing monetary rewards and punishments interact with PL during a texture identification task. We trained subjects on ten band-pass filtered, white noise textures in a same-different task, measuring accuracy while manipulating signal strength with the method of constant stimuli. Subjects were trained in adverse miss (AM), adverse false-alarm (AFA), and no adversity (NA) conditions over a period of five training sessions. In the NA condition, subjects received equal monetary rewards and punishments for each correct and incorrect identification. However, in the AM condition misses (identifying the same textures as different) were punished at a 100:3 ratio to rewards, and the AFA condition was subjected to similar punishment following false alarms. At the end of training, psychometric functions from subjects in the AM and AFA conditions exhibited a hard threshold: sensitivity was essentially zero to low-contrast patterns and the abruptly increased beyond a critical level of contrast. No such threshold was apparent in the NA condition. Hence, our results suggest that the reward structures in the AM and AFA conditions reduced sensitivity to weak signals and increased the slope of the psychometric function. Currently we are testing the effects of bias on PL across a wider range of payoff structures.

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33.4056 **Classification images reveal changes in the encoding of newly learned face dimensions** Fabian Soto[1](fabian.soto@fiu.edu); [1]Department of Psychology, Florida International University

A body of research suggests that learning to categorize objects along a new dimension changes the perceptual representation of such dimension, increasing its discriminability and its separability from other dimensions. However, little is known about exactly how the internal representations of individual objects change during such dimension learning. Here, we trained twenty participants to categorize faces that varied along two morphing dimensions. One of the morphing dimensions was relevant to the categorization task and the other was irrelevant. We used classification images to estimate the internal templates used by participants to identify four faces varying along the category-relevant and category-irrelevant dimensions, both before categorization training and after categorization training. The obtained classification images provide estimates of the exact stimulus information used by the participants to identify the faces at each stage. Thus, examination and comparison of the obtained classification images allowed us to determine exactly how the internal representation of these faces changed as a result of categorization training. We defined two ways in which the representation of the category-relevant dimension could have changed as a result of categorization training. First, the internal templates of two faces having opposite values in the category-relevant dimension could become negatively correlated, a result that has been found with some familiar face dimensions. Our results suggest that categorization training had an effect in this direction, but the effect was not significant. Second, the internal templates of two faces having the same value in the category-relevant dimension, but different values in the category-irrelevant dimension could become more similar, which would explain previously-observed increases in dimensional separability after categorization training. Our results show a robust effect of categorization training in this direction.

33.4057 **Subordinate-level training with novel objects differentially impacts neural and behavioral processing** Travis Jones[1](tjones0@ufl.edu), Hillary Hadley[2], Andrea Cataldo[3], Erik Arnold[3], Tim Curran[4], Jim Tanaka[5], Lisa Scott[1]; [1]University of Florida, [2]Northeastern University, [3]University of Massachusetts Amherst, [4]University of Colorado Boulder, [5]University of Victoria

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Previous research examining the acquisition of perceptual expertise has shown that subordinate-level training increases the amplitude of event-related potentials (ERPs) measured from the occipital-temporal regions during matching tasks involving cars and birds (Scott et al., 2006; 2008). Here, we examined whether training with artificial objects similarly impacts ERP components, whether ERP responses predicted behavioral responses (RT, accuracy (d')), and whether manipulations of color and spatial frequency impacted these measures. 22 adults participated in perceptual expertise training with two "families" of objects trained at the basic (Family A) or subordinate level (Family S). Each family included 10 unique species (labeled "A" through "J") each containing 12 exemplars. Before and after training, participants completed a serial same/different discrimination task with trained and untrained exemplars of trained species while ERPs were recorded. Images presented during the discrimination task were color, greyscale, high spatial frequency (HSF; > 8 cycles per image (cpi)), or low spatial frequency (LSF; < 8 cpi). Posttest N170 amplitude was significantly greater for subordinate-trained objects relative to basic-trained objects and was also greater in response to low and high spatial frequency images relative to color and greyscale images. Latency analyses revealed a significantly later peaking N170 in response to low-spatial frequency images relative to all other conditions. At posttest, N170 latencies measured from left-occipital electrodes predicted reaction time such that as N170 latency increased, RT increased for subordinate trained and untrained color exemplars. No significant correlations were present after basic-level training or for the image manipulations. In addition, no significant correlations were present for N170 amplitude or for the right hemisphere. Results extend previous reports and further add that subordinate-level training with novel objects differentially effects neural processing for the N170 ERP component. Further, the present results provide evidence of a significant brain-behavior correlation in response to subordinate-level training.

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33.4058 An unfamiliar expression: exploring the role of symbolic elements in processing cartoon faces

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A unique trait of cartoon imagery is that it employs abstract symbolic elements, which require learning or culture to understand, in addition to literal iconic elements that resemble features of the real world. Our previous research has demonstrated that more abstract or "cartoonized" iconic images of faces communicate emotion more quickly and efficiently than photorealistic images of faces, and that such heightened communicative value relies on low-level features such as simplicity and contrast. Outstanding questions concern whether iconic facial features (e.g., :)) can be replaced with symbolic ones (e.g., :#) and still be rapidly perceived as being "facelike" with the acquisition of emotional meaning. In the present study we employed a face-sensitive ERP component, the N170, as an index to examine this question. EEG was collected during a probe task in which 23 participants labeled expressions on cartoon faces (happy, sad, neutral, and no emotion) that had either iconic or symbolic features. A control condition employed the same stimuli without eyes, eliminating the facelike configuration. This task was performed before and after a training task in which participants learned that symbolic features represented facial emotions and were trained to criterion. Peak N170 activation was extracted 160-220ms after stimulus onset. Results showed that N170 amplitudes were altered with training for symbolic faces only, such that after the training task they were equivalent to those observed for iconic faces. No changes were observed for iconic stimuli or either type of stimulus in the control condition. These results indicate that simply learning that arbitrary symbols conveyed emotional meaning increased rapid and relatively automatic perception of symbolic faces as "facelike." Follow-up studies explore which aspects of face stimuli, such as the presence of specific features or configural arrangements, are more pliable to symbolic manipulations.

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33.4059 Moderating Effects of Visual Attention and Action Video Game Play on Perceptual Learning

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In recent years there has been substantial controversy regarding the reliability of observed patterns of perceptual learning. A number of factors have been suggested to account for individual differences in what subjects learn and when, although many of these factors have been studied with small sample sizes. We present a large perceptual learning study including 112 subjects in two experiments in which we examine effects of visual attention and action video game play on baseline performance, learning, and transfer in a Texture Discrimination Task. In Experiment 1 stimulus difficulties were randomly intermixed throughout training, in Experiment 2, different stimulus difficulties were presented in sequential blocks. In each Experiment, we examined learning for a trained stimulus configuration as well as transfer to an untrained background orientation. We find subjects with better visual attention skills, as measured by the Useful Field of View task, demonstrate superior overall performance on the TDT ($F(2,104) = 6.75$; $p = 0.002$). In contrast, action video game experience was unrelated to performance on this task ($F(2,104.16) = 0.229$ $p = 0.796$) and unrelated to performance on the UFOV ($F(2,106) = 1.69$; $p = 0.190$). This latter finding stands in contrast to previously reported research. We failed to find statistically robust support for the hypothesis that visual attention skill interacts with the amount learned ($F(2,104) = 2.08$; $p = 0.130$) or the degree of transfer ($F(2,104) = 2.32$; $p = 0.103$). The relationship between action video game play and learning was not significant ($F(4,100) = 0.77$; $p = 0.530$), and there was no interaction with transfer ($F(4,100) = 0.68$; $p = 0.608$). Together these results suggest that Attention Skill and Action Video Game have less consistent impact on Perceptual Learning than previously suggested.

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33.4060 Training Peripheral Vision to Read Korean Characters Transfers to English Characters: Evidence for A Non-symbol-specific Mechanism

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Purpose: The visual span refers to the number of adjacent characters that can be recognized in a single glance. In peripheral vision, the visual span for English is enlarged after perceptual training on a task requiring recognition of letter triplets. Here, we examined the transfer of training benefits from Korean to English characters. A lack of transfer would suggest a symbol-specific mechanism underlying training-related changes, e.g. better templates for recognition. Successful transfer would suggest a non-specific mechanism, such as a reduction in crowding, the inability to recognize objects in clutter. Method: Participants were 4 male and 5 female native Korean speakers (also proficient in English). In pre- and post-tests, we measured visual spans for single Korean letters (vowels and consonants), single Korean characters (composed of 2 or 3 letters), triplets of Korean characters, and English single letters and triplets. Training (1.5h * 4 days) consisted of repetitive visual-span measurements for Korean character triplets. Results: At baseline, the size of visual spans was negatively correlated ($r=-0.96$) with the perimetric complexity of the type of symbols, with visual-span size decreasing from single English letter = single Korean letter > single Korean character = English letter triplets > Korean character triplets. Training with Korean character triplets enlarged the visual spans for Korean single characters and character triplets. Such benefit also transferred to English letter triplets. Training-related enlargement was primarily due to a reduction of within-symbol crowding (for Korean characters) and between-symbol crowding (for triplets of Korean and English characters). Conclusion: The transfer of training benefits from Korean to English characters shows a non-symbol-specific mechanism underlying training. This suggests that the sensory limit underlying the visual span for script recognition is shared across languages. The generalization of training across types of symbols enhances the clinical potential of this training for individuals with central-field loss.

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33.4061 **Visual Speed Sensitivity in the Drum Corps Color Guard**
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Introduction: Drum corps color guard experts spend years developing skills in spinning rifles, sabers, and flags. Their expertise provides a unique window into factors that govern sensitivity to the speed of rotational and radial motion. Rotational and radial motion register in the Medial Superior Temporal (MST) region of the primate visual system, according to prior neurophysiological research (Tanaka & Saito, 1989; Duffy & Wurtz, 1991). To the extent that shared neural events govern rotational and radial speed sensitivity, one would expect expertise on either task to transfer to the other. One similarly would expect shared neural events to generate correlations between rotational and radial speed sensitivity. We psychophysically evaluated these predictions via visual speed sensitivity tests on drum corps color guard experts and controls. Method: Drum corps color guard experts (n=26), drum corps low brass experts (n=29), and age-matched controls with no drum corps experience (n=24) viewed displays containing bilaterally presented dynamic plaid stimuli. The "standard" plaid either expanded / contracted at two octaves per second (radial task), or completed two rotations per second (rotational task). The "test" plaid moved slower than the standard by various amounts. The standard and test sides varied randomly across trials. Participants reported which side contained faster motion. Results: A modest but statistically significant group-by-task interaction indicated that, relative to low brass experts, color guard experts exhibited greater rotational speed sensitivity but worse radial speed sensitivity ($F(1,53)=8.806$, $p=0.004$, $p\eta^2=0.142$, power=0.83). This pattern replicated three weeks later among the same participants, and also when controls who had no drum corps experience replaced low brass experts. Additionally, radial speed sensitivity and rotational speed sensitivity each exhibited significant test / retest reliability ($p< 0.001$), but near-zero between-task correlations (n.s.). Conclusion: The findings match predictions that follow from a dissociation between the neural events governing rotational and radial speed sensitivity.

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33.4062 **Investigating The Impact of Demographic Features on Body Size Discrimination**
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Little is known regarding how demographic features affect visual categorization of body size. Here, we assessed how individuals' categorization performance is impacted by gender and race. Specifically, we investigated 1) The impact of observed subjects' race and gender on observers' categorization of body images/stimuli and 2) The impact observers' race and gender had on their categorization performance. We designed an experiment to study the potential effects of these features by presenting a condition rich paradigm (24 conditions) comprised of 2 gender body stimuli (male, female), 3 race body stimuli (African-American, Caucasian, Green Avatar as a control race), and 4 categories of body mass index (BMI; underweight, normal, overweight, obese). Preliminary results demonstrated that volunteers' performance as measured by accuracy was modulated by the race and gender of the stimuli they observed. Specifically, we found a significant main effect of race of the stimuli, as categorization performance was best for the Green Avatar, followed by Caucasian and then African-American. A significant main effect of BMI weight categories was observed, as volunteers performed best for normal weight stimuli, then underweight and overweight, and worst for obese. Intriguingly, a significant interaction between gender and weight category was found. While volunteers were more accurate in categorizing male stimuli that were underweight and normal relative to overweight and obese, they were more accurate for categorizing female stimuli that were overweight and obese. We also observed a significant interaction between race, weight category, and volunteers' gender. Female volunteers were more accurate for underweight than overweight when viewing African-American stimuli. In contrast, male volunteers performed equally for underweight and overweight body stimuli. Our results illustrate that body size perception is not uniform across observers and can be influenced by demographics of both the observers and the stimuli they observe.

33.4063 **Mutual transfer between visual and auditory temporal interval learning supports a central clock in temporal processing**
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Temporal perceptual learning shows specificity to the visual or auditory modality, or asymmetric partial transfer from auditory to visual, but not vice versa. These findings are interpreted as evidence for distributed, rather than central, temporal processing (Ivry & Schlerf, 2008). For visual perceptual learning, location and orientation specificity can be eliminated with double training, indicating that learning specificity may not be used to infer the mechanisms of perceptual learning (e.g., Xiao et al., 2008). Here we investigated whether double training can eliminate the modality specificity in temporal learning. We first replicated asymmetric partial transfer results between auditory and visual learning of a temporal-interval discrimination (TID) task with standard training. The standard interval was marked by a pair of auditory beeps or visual gratings at 100-ms. The subjects practiced either the auditory or the visual TID task for 5 sessions. Visual TID learning had no impact on auditory TID performance ($p=0.65$), while auditory TID learning improved visual TID performance ($p=0.005$), although not as much as direction visual TID learning ($p=0.028$). However, complete learning transfer was evident with double-training. When visual TID learning was paired with an auditory frequency discrimination task at the same 100-ms interval, auditory TID performance was improved similarly to direct auditory training ($p=0.051$), indicating complete cross-modal learning transfer. Similarly, when auditory TID learning was paired with a visual contrast discrimination task at the same 100-ms interval, visual TID performance was improved equally as direct visual training ($p=0.95$), again indicating complete cross-modal learning transfer. In both cases we found no significant impact of practicing auditory frequency discrimination or visual contrast discrimination alone on TID performance. Our results suggest mutual and nearly complete learning transfer of TID learning between visual and auditory modalities, which are consistent with a central temporal processing mechanism shared by different modalities.

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Attention: Neuroimaging

Sunday, May 21, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.4064 **Neural markers of efficient response inhibition in parietal cortex**
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Introduction: Response inhibition, the ability to suppress inadequate but prepotent response tendencies, is a cognitive-motor effortful process. Brain mechanisms typically reported for response inhibition are extensive, and there is an ongoing controversy evolving mainly around the role of frontal regions. In the current study we assessed response inhibition using a novel Go/No-go design and fMRI. Furthermore, we examined participants with attention-deficits/hyperactivity disorder (ADHD), a population with prominent dysfunction of response inhibition, to investigate brain correlates of atypical inhibition. Method: Using fMRI we recorded brain activity while participants performed a Go/No-go task with frequency manipulation of trial type. Although inhibition is required in all No-go trials, rare-No-go cases (25%) create a prepotent response and a strong demand for inhibi-

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tion, while prevalent-No-go cases (75%) require very little inhibition effort. Thus, contrasting No-go trials from these different contexts pinpoints inhibition-related brain activation. Furthermore, among participants with ADHD, we assessed behavioral symptom severity using the Adult ADHD Self-Report Scale (ASRS), and examined the relationship between ADHD symptoms and inhibition-related brain activation. Results: Unlike previous reports, our unique design allowed us to isolate distinct clusters of activation in bilateral intraparietal sulcus (IPS) and left temporoparietal junction (TPJ). These regions showed greater activation to rare-No-go trials than to prevalent-No-go trials in healthy controls. Interestingly, this effect was absent in the ADHD group. Strikingly, parietal modulation by inhibition demand was associated with ADHD symptom severity, such that higher severity corresponded to reduced modulation in parietal cortex. Conclusions: Results of the current study highlight the contribution of the parietal cortex to inhibitory processes, while casting doubts on the specificity of frontal activation in such processes. Furthermore, we argue that elevated activity in bilateral IPS and left TPJ may serve as a neural marker of efficient inhibition of a pre-potent response and may be useful in identifying atypicalities.

33.4065 Tracking the neural fate of visual representations across fluctuations in sustained attention

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Attention during cognitive tasks fluctuates between periods of optimal (accurate and consistent) and suboptimal (error-prone and variable) states. Though previous studies have associated attentional control regions (e.g., dorsal attention network, DAN) with these fluctuations, how the relationship between attentional and perceptual regions gives rise to optimal states is currently unknown. The present research uses representational connectivity analysis to examine how fine-grained visual information is transmitted from visual to higher-order cortical regions during optimal (in-the-zone) and sub-optimal (out-of-the-zone) attentional states. To accomplish this, participants (N=145) performed the gradual onset Continuous Performance Task (gradCPT) during an fMRI scan. Participants viewed a series of city or mountain scenes, responding to cities (90% of trials) and withholding responses to mountains (10%). First, a visual ROI (corresponding to bilateral lateral occipital cortex) was functionally identified as voxels sensitive to a stimulus-driven difficulty timecourse based on the similarity between the city and mountain images. Previous research has shown that increased city-mountain similarity results in response errors and slower RTs. Next, two representational similarity matrices (RSMs) were derived by computing pairwise correlations between the activation patterns for each city exemplar (n=10) within the visual and DAN ROIs. Representational connectivity (RC) was quantified as the correlation between the these two RSMs. Importantly, RC was computed separately for in-the-zone (low RT-variability) and out-of-the-zone (high RT-variability) trials. We found that the RC between the visual and DAN RSMs was greater while participants were in-the-zone ($r=0.72$, $p< 0.001$) than out-of-the-zone ($r=0.19$; $p=0.20$). Similar differences were observed in the fronto-parietal control network, while other large-scale brain networks tested showed no effect. These results suggest that optimal, but not suboptimal, states are associated with the integration of fine-grained visual information into large-scale task-positive brain networks. More broadly, this work provides a novel way to conceptualize optimal brain states within an information processing framework.

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33.4066 Attentional modulation of layer-specific BOLD signals in human early visual cortex

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Human early visual cortex consists of six layers, with distinct roles in feedforward, lateral, feedback connections. The nature of attentional modulation at different cortical layers of visual cortex remains unclear. With submillimeter-resolution fMRI at 7 Tesla, we investigated the top-down attentional modulation of layer-specific BOLD signals in human early visual cortex . Stimuli were full-field checkerboard patterns counterphase flickering at 7.5 Hz. In the attend-checkerboard condition, subjects were instructed to detect the occasional spatial frequency change of the checkerboard. In the attend-fixation condition, they performed a demanding central fixation task and the checkerboard stimulus was task-irrelevant. The checkerboard pattern was presented at 50% contrast in experiment 1, and 5% contrast in experiment 2. FMRI Data were acquired with a single slice high-resolution passband b-SSFP sequence (0.64*0.64 mm in-plane resolution, 3mm slice thickness, placed perpendicular to the calcarine sulcus). Experiment 1 showed that in the attend-fixation condition, the stimulus-driven response to the high contrast checkerboard peaked in the mid-layers of the gray matter, while attending to the checkerboard generated the strongest attentional modulation in the superficial layers, i.e., voxels close to the gray matter surface. In experiment 2, the low contrast checkerboard stimulus, when not attended, produced minimal activities in the visual cortex; but again the response in the attended condition was strongest in the superficial voxels. The response from V1 to V3 showed similar patterns: stimulus-driven activities peaked in the middle layers, while the modulation of top-down spatial attention was strongest in the superficial layers.

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33.4067 Independent and overlapping neural representations of saccades, attention shifts, and reference frames

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When changing our focus from one location to another, we can either move our eyes or shift our attention covertly. Previous research indicates that saccade execution and attention shifts might share underlying brain networks, including intraparietal sulcus (IPS) and frontal eye field (FEF) (Corbetta & Shulman, 2002). To further explore how neural representations of saccades and covert attention shifts interact, we acquired fMRI data during a combined saccade and covert attention task. Participants began each trial by fixating at one of two fixation points while covertly attending to one of three rapid serial visual presentation (RSVP) streams (left, center, right of screen). There were four critical conditions. On eyes-fixed trials, participants either held attention at the same initial location (hold eyes, hold attention) or shifted attention to another stream midway through the trial (hold eyes, shift attention). On eyes-move trials, participants made a saccade midway through the trial, while maintaining attention in one of two reference frames: (shift eyes, retinotopic attention) and (shift eyes, spatiotopic attention). The retinotopic condition involved holding attention at a fixation-relative location but shifting relative to the screen, whereas the spatiotopic condition involved holding attention on the screen-centered location but shifting relative to the eyes. We used multivariate pattern analysis (MVPA) to decode information about saccades (eyes-fixed vs. eyes-move), attention shifts (hold vs. shift attention), and reference frames (retinotopic vs. spatiotopic attention). Regions where saccade information could be decoded overlapped with those where attention shifts could be decoded, including parts of IPS, superior parietal lobe (SPL) and FEF, consistent with previous literature. Moreover, reference frame information could be decoded in additional regions (e.g., left SPL) that did not fully overlap with saccade-decoding or attention-shift-decoding regions. The reference frame results might reflect an integrated neural representation of saccades and covert attention shifts, beyond their independent and overlapping representations.

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33.4068 Neuronal and temporal correlates of “Gist” processing

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Humans can rapidly extract the ‘gist’ of images, using global image and summary statistics. This allows for quick extraction of information for multiple categories, but these outputs can interfere destructively depending on the task at hand (Evans et al., 2011). Using rapid event-related fMRI and EEG in two experiments, we investigated the neuronal correlates of gist processing and their modulation due to changing task contingencies. In the fMRI experiment a combination of noise masks and two different category images were presented in quadrants of the visual field simultaneously for 200 ms. Observers reported the presence and quadrant of a pre-defined target category. We measured BOLD responses in pre-localised, category selective cortical regions and conducted additional whole-brain analyses. In the EEG experiment observers were also asked to categorize briefly presented (25 ms) pre-cued images from six categories. Multivariate pattern analysis (MVPA) of EEG responses was used to identify patterns of activity across the scalp. FMRI results show category-selective activation in extrastiate areas, supporting their involvement in gist perception, and EEG data revealed that gist is discriminable from 50 ms post stimulus onset. No top-down-driven activation in target locations was observed in early visual cortex, consistent with the observation of gist extraction without the ability to localize the target. Responses to changes in the image category task contingencies during the experiment were evident only in frontal areas. Consistent with this, changes in task contingency influenced the pattern of EEG responses only from around 300 ms post stimulus onset. In conclusion, we find that activity in category specific extrastriate visual areas correlates with spatially non-specific, rapid gist perception and that these areas presumably pool signals from earlier areas with lower featural selectivity. Lastly, the effects of task contingencies modulate this rapid gist processing only at the decisional stage.

33.4069 Visuospatial attentional selectivity within the cerebellum

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The cerebellum is traditionally associated with fine motor control; however, there is growing evidence linking the cerebellum to cognitive function (e.g., Stoodley et al., 2012). Brissenden et al. (2016) showed that portions of the cerebellum, which exhibit functional connectivity with the cortical dorsal attention network (DAN), are recruited by visual working memory and visual attention tasks in a load-dependent manner. Here, we demonstrate that these same DAN-coupled cerebellar regions contain visuospatial representations that code for the location of attentional deployment. Participants (N=9) performed a lateralized VWM change detection paradigm with oriented bar stimuli in an fMRI scanner. Prior to each block, participants were cued to covertly attend either the left or right visual hemifield. Cerebellar regions-of-interest (ROIs) were defined via a resting-state functional connectivity analysis using cortical networks (Yeo et al., 2011) as seeds. To investigate whether cerebellar network ROIs are sensitive to the allocation of spatial attention, we trained support vector machines using a nested cross-validation procedure to discriminate between the two possible locations of attentional deployment. Due to literature implicating the cerebellum in oculomotor processes, we also examined whether the same cerebellar fMRI data contain information about eye movements using linear support vector regression. Permutation tests revealed that the cerebellar DAN ROI was only the cerebellar region that could decode the attended hemifield above chance ($p = 0.014$, corrected). Additionally, visuospatial classification performance in the cerebellar DAN ROI matched that of frontal nodes of the DAN [$F(2,18) = 0.49$, $p = 0.62$]. Cerebellar DAN BOLD activity was shown to contain no predictive information about eye movements or eye position. These findings provide further evidence for the active participation of cerebellar regions in attentional brain networks, and suggest the cerebellum may be more actively involved in the orienting of attention than previously believed.

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33.4070 Predicting an individual's own Dorsal Attention Network from their functional connectivity fingerprint

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Over a decade ago, Maurizio Corbetta and Gordon Shulman introduced the concept of the dorsal attention network, a set of regions that mediate top-down attention. Since then, the dorsal attention network has been reliably observed across studies of goal-directed attention. Nevertheless, there exists great variability in the location and degree of activation across individuals. The neural architecture that may underlie an individual's specific and idiosyncratic activation pattern remains unexplored. We hypothesized that an individual's connectivity pattern may be strongly associated with their particular pattern of activity, since connectivity is the principle neural component that defines the computational domain of a brain region. Here we used the pattern of intrinsic functional connectivity of an individual to model and predict the location and activation strength of their own dorsal attention network. We used the modeling approach first described by Saygin et al. 2012 and later extended in Osher et al. 2015 and Tavor et al. 2016. This model, which links activations patterns of single voxels as a function of connectivity to the rest of the brain, can be applied to other attentional tasks that are capable of recruiting the dorsal attention network, such as multiple object tracking, change detection, or visual 2-back tasks. This demonstrates that connectivity can produce comparable predictions of an individual's dorsal attention network as various localizers. Lastly, an analysis of the final model coefficients describes the connectivity patterns that best define an individual's dorsal attention network.

33.4071 Mapping Task Response Profiles in Visual-biased Frontal Cortex

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Conventional wisdom suggests that frontal cortex is specialized for higher-level cognitive processes, such as spatial cognition and executive control. Recently, our laboratory demonstrated that caudolateral frontal cortex contains multiple, discrete, bilateral visual- and auditory-biased regions (Michalka 2015). Two regions, superior and inferior precentral sulcus (sPCS and iPCS), were recruited during visual vs. auditory attention. We also recently showed that visual- and auditory-biased regions in frontal cortex are revealed by contrasting functional connectivity to visual-biased regions in parietal cortex against auditory-biased regions in temporal cortex. Frontal regions exhibiting stronger connectivity with posterior visual regions not only include task-defined visual-biased regions, but also extend into additional portions of frontal cortex, such as rostral middle frontal gyrus (rMFG) (Tobyne, under review). Here, we further explore visuospatial task activation in frontal regions that are preferentially functionally connected to posterior visual structures. In individual subjects, we contrasted fMRI resting state functional connectivity between caudolateral frontal cortex and posterior visual and auditory seeds using a bivariate regression analysis. The resulting connectivity-defined visual-biased regions (sPCS, iPCS) were divided into two subdivisions: one that was recruited in the Michalka (visual vs. auditory) attention contrast ("original region") and an adjacent region which was not ("buddy region"). We examined activation within each subregion in multiple visuospatial fMRI paradigms, including multiple object tracking and visual short-term memory. Preliminary results suggest that activation during visuospatial tasks overlaps strongly with both "original" and "buddy" sPCS and iPCS regions, but rMFG is not as robustly recruited. Visual-biased regions identified by preferential functional connectivity appear to have different response profiles for different visuospatial tasks. We further suspect that the large sPCS and iPCS regions seen in many vision studies contain specialized sub-regions whose task response varies. Bivariate regression of functional connectivity profiles may be more powerful than traditional task activation in identifying specialized cortical structures.

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33.4072 Attentional load parametrically modulates responses within human FEF and early visual cortex

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Although attention is known to modulate visual responses, the computations by which this modulatory influence emerges remain unclear. Here, we used fMRI to parametrically assess the nature of modulatory signals in regions of the putative dorsal attentional network and their effect on the responses within visual cortex. To do so, we developed a paradigm that allowed for fine-grained manipulation of attentional load, a feature lacking in common attentional tasks. In this task, which we coin the Numerosity Judgement Paradigm (NJP), participants viewed a dense array of small, colored (red or blue) rectangles near fixation. They were asked to judge, from trial to trial, which of the two colors was dominant in this array. Changing the ratio of the rectangles with the dominant color enabled us to modulate

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the amount of attentional load directed toward this array; when the ratio was close to 1, accomplishing the task did not require much attention, but when the ratio was closer to 0.5, more attentional effort should have been directed toward the array. Around the NJP stimulus, an annulus comprised of pink noise was shown to participants; this allowed us to test the degree of attentional withdrawal from fixation. As expected, we observed a drop in performance for the NJP as a function of task difficulty, which coincided with an enhancement in activity within the dorsal attentional network, particularly in the frontal eye fields (FEF). This parametric increase in the activity of the attentional areas was accompanied by a graded decrease in responses within early visual areas corresponding to the unattended noise stimulus. These results give a precise profile of the relationship between the rise and fall of activity within attentional networks and visual areas, demonstrating how attention operates as a modulatory signal.

EYE MOVEMENTS: COGNITION

Sunday, May 21, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.4073 On utilizing eye movements to inform and guide subsequent thought

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Eye movements are a window into ongoing unconscious cognition. Here, we ask (i) if eye scan patterns provide a sneak peek into future thought and overt response, and (ii) if experimental manipulations can alter subsequent thought. i) Can the eye movements of a subject prior to response reliably predict it? We asked subjects to think of a number, then anticipated their choice from their eye scan data. Subjects (n=50) were shown a number line (with no numbers) for 300 ms followed by a blank screen and an oral prompt: "Think of number 1, 2, or 3 and say it out loud". Features for the pattern classification were extracted from the eye scan data over the time period before (predictive) and after the number choices were presented but before overt subject response. Classifier test performance (random forest; leave one out cross-validation, or LOOCV) was 92% (=46/50) correct. Predictive features alone correctly predicted subject choice on 84% of cases. Thus, an individual's eye scan data foretells their response in an abstract number choice task. ii) Can we drive subject eye position and/or spatial attention so as to reliably alter their subsequent thought? We yoked the subject's attention with an attention-grabbing cue to a part of space and asked if this systematically influenced the number ("1"/"2") the subject later thought of. Subjects were shown a video on the screen's left (n=20) or right (n=20) or no video at all (n=20) prior to the trial and respectively chose "1" 90/5/65% of the time. Thus, an external stimulus successfully altered the number one will think of. Our findings thus demonstrate that eye movements both inform and guide subsequent thought. We are currently exploring if temporal ordering of choice presentation imposes a spatial mapping or if an innate spatial mapping onto physical space is required.

33.4074 Pupil dilation reveals the implicit prior processing of the insight to the hidden image

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Insight is sudden comprehension of the new situation. For example, when we see an ambiguous image, a sudden insight occurs to us before we comprehend the image. This study aims to investigate the implicit preparation for the insight. Here, we represented the hidden image of the lattice-shaped dots movie, which was created by the dots methods (Moca et al., 2011) from the original image to control the stimulus difficulty and measured pupil diameter while participants were asked to respond whether they recognized the object in the movie. Thus, we hypothesized that the pupil dilation should be reflected by the implicit processing of the insight to the hidden image. In the Exp.1, participants were instructed to respond when they came up to mind what the object is. The results showed that the averaged pupil dilation before the insight was larger in the recognition trials than in the no-recognition ones. This implies that the pupil dilation reflected the spontaneous processing to reach the insight, not the recognition state. Therefore we demonstrated that the pupil dilation before the insight by manipulating the presentation time (1.5s vs. 6s) (Exp.2). The results of pupil dilation were significantly similar to those in the Exp.1. Crucially, despite the fact that participants could not comprehend in short presentation condition (1.5s), the pupil was dilated depending on the subsequent insight in long presentation condition. Moreover, the pupillary response can not be explained by the cognitive effort such as the motivation for solving the problem from self-confidence response in their comprehension. These suggested that the pupil dilation affected by the LC-NE system activity reflected the integration of the pre-processing between the visual information and the memory retrieval.

33.4075 Fixation-related Potentials as a Natural Index of Task Difficulty: Single-trial Classification

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Eye movements are a pervasive element of our everyday interactions with the environment and are essential for many real-world tasks. As such, they provide a natural and frequent event upon which to examine evoked neural activity related to visual perception. Previous studies have shown that the evoked activity around each fixation is a mixture of bottom-up (stimulus driven) and top-down (attentional control) components, and thus modulated by cognitive processes associated with a given task. In this study we sought to quantify the effect of task difficulty on the lambda response, an early component of the fixation related potential (FRP). While prior experiments have shown changes in the lambda amplitude as a function of task difficulty, it is not clear if this effect can be measured on a single-trial basis. We addressed this question by parametrically modulating visual task difficulty in two different paradigms that utilized eye movements. In the first instance, we manipulated difficulty via the working memory load of an N-Back task where gaze position was systematically guided across a stimulus grid. In the second instance, we used a modified Tetris game where difficulty was manipulated via tetrad fall speed while gaze position was unconstrained. Applying linear discriminant analysis to the FRP we were able to classify fixations occurring under conditions of high versus low task difficulty, in both paradigms, at a level of accuracy significantly above chance. As expected, these classifiers identified the lambda component as containing the most discriminant activity within the fixation epoch. We compare these results to other established neural and physiological correlates of task difficulty, also measured during the experiment. This approach may provide a more direct way to index cognitive demands in real-world tasks without having to rely on secondary measures or obtrusive stimulus probes.

33.4076 Information Fusion Based on Fixation Patterns and Semantic Analysis for Observer Identification during Reading

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This work presents a novel technique to identify unique individual readers based on an effective fusion scheme that combines fixation patterns with syntactic and semantic word relationships in a text. Previous eye-movement identification methods for reading used intricate eye-movement variables that were sensitive to various factors unrelated to reader identification (Holand & Oleg, 2011; Bayat & Pomplun, 2016). In contrast, the current technique was developed based on only eye fixation (location and duration) variables that are interpolated in a vector representation of words of a text. We use eye-movement data that were previously collected in our lab by Attar et al. (2016). In this experiment, forty participants read six easily readable passages with general topics (food, health, science, and history). The vector representations of words in all six passages were computed using the skip-gam model that provides linear structure representations of words (Mikolov et al., 2013). This pre-trained Google News corpus word vector model consists of 3 million 300-dimensional English word vectors. Using this vector space model, each word was mapped into a 300-dimensional vector. Moreover, a 3-dimensional weight vector was adopted for each word in a passage by evaluating the distance of the nearest fixation point to that word and its immediate neighbors. This weight vector was multiplied by the vector representations of corresponding words. By computing the average of the resulting vectors, a 300-dimensional feature vector was derived for each passage associated with each participant. By combining Logistic and Multilayer Perceptron as our classification algorithms, we reached an overall accuracy of 96.84% which is higher than the accuracies obtained by other eye-movement based biometric methods. The present finding suggests that an average vector representing interpolated eye fixation and sematic text information differs systematically across individuals, which leads to high and consistent identification accuracy.

33.4077 What eye movement and memory experiments can tell us about the human perception of visualizations

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What makes a visualization (a graph, chart, or infographic) memorable? Where do people look on a visualization during encoding and retrieval? What aspects of the visualization can later be recalled from memory? Studying these questions in the context of visualizations allows us to expand our understanding of human perception to complex visual content beyond natural scenes. We ran a series of experiments in the lab and on the crowdsourcing platform Amazon's Mechanical Turk (MTurk). In the lab, we recorded people's eye movements as they viewed infographics for 10 seconds each, with a retrieval task at the end of 20 minutes. In the final phase, participants provided descriptions of the visualizations from memory. On MTurk, we ran a series of memorability tests, and separately, a series of description tasks where participants clicked on blurred visualizations to reveal small bubble-like regions at full resolution. We compared the consistency of human memory and the consistency of human attention on visualizations, in lab and online settings. First, we find that people are consistent in where they attend and what they remember in visualizations. Second, we discover some qualities of visualizations that tend to make them more memorable. Importantly, we show that a visualization that is memorable at-a-glance can often also be recalled and described with higher fidelity. Third, we quantify which elements of visualizations people tend to focus their attention most on. We find that text, and especially titles, are particularly important; and that visual elements are not as distracting as initially hypothesized. Finally, we make our full dataset of thousands of visualizations, eye movements, memory scores, and text descriptions available to the community (massvis.mit.edu). This dataset presents the opportunity of delving into a variety of old and new perception questions using a novel image type for such investigations.

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33.4078 Examining the influence of ttask and scene alternations and repetitions on eye movements during scene viewing

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The extent to which tasks and stimuli repeat or alternate across trials is known to influence performance, with oculomotor behavior being impacted by task-switching (Mills et al., 2015). Previous examinations of task set and visual behavior, however, have generally required observers to perform different tasks on different scenes, thus neglecting the fact that an observer's task can change even when the visual input remains the same. The present study examined how task switching influences visual behavior when scenes are presented multiple times—does scene repetition moderate the effects of task switching and, if so, is repetition beneficial or detrimental to subsequent processing? Participants viewed scenes while performing either a search (is there a small N or Z embedded in the scene), memorization (post trial forced-choice recognition), or evaluation (rate pleasantness of scene on 7 point scale) task. Task and scenes were presented with varying lags such that a) the same task could be performed on the same image up to 3 times, b) the same task could be performed on different images up to 3 times, or c) an image could repeat up to three times with a different task performed on each trial. Thus, both the task and the scene could either alternate (full alternation) or repeat (full repetition) across lags, or either the task or the scene could alternate while the other was repeated (partial repetition). We found that scene repetition enhanced the effect of task-switching on eye movements, whereas scene alternations diminished it. These results suggest that perceptual processing transferred between tasks and memory for the previous task/scene exposure moderated the impact of task switching on visual behavior.

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33.4079 The relationship between eye movements & memory performance during scene viewing is influenced by viewing mode

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Oculomotor kinematics and visual behavior vary as a function of both task-set (Castelhano et al., 2009; Henderson et al., 1999; Mills et al., 2011; Smith & Henderson, 2009; Yarbus, 1967) and task-switching (Mills et al., 2015). One parameter that seems to be influenced by task and switch type is the speed by which individuals shift from a global (long saccades, short fixations) to a local (short saccades, long fixations) viewing mode. An earlier shift in viewing mode may reflect a differential emphasis for general spatial information processing vs. more specific object encoding. Velichkovsky et al. (2002, 2005) demonstrated local-type fixations to be positively related to object identification on a recognition task, suggesting that memory accuracy may be influenced by viewing mode. Though memory tasks are often included in task-set and task-switching studies, memory performance is not typically collected nor analyzed in relation to visual behavior, making it unclear as to whether task-related variation in eye movements may be reflective of a task-dependent shift from spatial-to-identity processing. To examine this issue, subjects viewed scenes while performing either a memorization, search, or evaluation task. When the task was memorization, each trial was followed by a forced-choice recognition test in which scenes were identical save for a single global (e.g., entire image flipped) or local (e.g., object removed/added) change. When collapsed across all participants, memory performance was unrelated to kinematics, however, there were considerable individual differences in memory performance and variability as a function of change type. Specifically, the earlier participants shifted to a local viewing mode, the more likely they were to detect a local change whereas a longer sustained global viewing mode led to superior performance for detecting global changes.

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33.4080 Increased scene exploration does not enhance memory

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Research has shown that eye movements are beneficial for the perception of scenes. Specifically, we have previously shown that when eye movements are disallowed during the encoding of a scene in a memory experiment, recognition accuracy falls to chance at test. This suggests that eye movements during the first viewing of a scene, used to visually explore and encode the scene, are critical for accurate subsequent memory. Here we probe whether it is possible to enhance memory by encouraging people to explore scenes more thoroughly by prompting them to make more eye movements during scene viewing. Seven participants viewed photographs of real-world scenes, followed by a new-old memory task. They were either allowed to look around the scene as they pleased (LOOK condition), or were instructed to make more eye movements throughout the scene (EXPLORE condition). An index of exploration behaviour was calculated as the root-mean-square-distance (RMSD) from initial fixation, weighted by fixation duration. Participants were able to follow instructions, in that their RMSD was significantly higher in the EXPLORE condition (5 degrees) than the LOOK condition (4.4 degrees, $p < 0.05$). However, recognition accuracy (hit rate) did not differ between conditions, meaning that the extra exploration did not have an influence on memory. These results, along with the results from our previous study, demonstrate that eye movements are necessary for proper encoding and thus accurate subsequent memory. However, once overt attention is already deployed, greater exploration within

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the same timeframe does not increase encoding efficiency. Therefore, the link between memory and scene exploration is likely a reflection of overt attention during encoding.

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33.4081 Eye-Movements Search for Comprehension during Bridging Inference Generation in Wordless Visual Sequential Narratives

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The current study investigated attentional selection during bridging inference generation in wordless visual sequential narratives. Comprehension processes, such as inference generation, have shown clear effects on eye-movements in reading, and more recently modest effects in studies with video and sequential narratives. Two competing hypotheses were tested: Computational Load: During inference generation, eye-movement locations will be driven by bottom-up saliency, and fixation durations will increase due to higher computational load. Visual Search: During inference generation, eye-movement locations will be driven by search for inference-relevant information, producing more fixations. Wordless children's picture stories were used. Bridging inference generation was induced through ellipses placed in the narrative during 3-image target episodes. In the target episodes, half the participants saw the full three image sequences, while the other half, in the ellipsis condition, did not see the highly inferable action in the middle of the target episodes. Previously, we showed that, in the ellipsis condition, viewers readily inferred the action, as shown by increased viewing times and think-aloud protocols on the image immediately following the ellipsis in the sequence. The current study added eye-tracking to test the effects of inference generation on eye-movements. Results showed participants in the ellipsis condition made more fixations, but had similar fixation durations to participants in the non-ellipsis condition. Fixation density heatmaps were then used to test whether fixations in the ellipsis condition were more likely to go to locations uniquely important for generating the inference than in the non-ellipsis condition, by comparing both to inference-informative heatmaps created from ratings by a separate group of participants. Overall, ellipsis condition participants were more likely to look at areas important for generating the inference. These results support the Visual Search Hypothesis in that during inference generation, participants make eye-movements to search for information that uniquely aids in drawing the inference.

33.4082 Eye movement strategies during search of graphs with relevant and irrelevant information

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Eye movements provide insights about strategies used to interpret graphical information (Carpenter & Shah, 1998). Subjects searched bar or line graphs to answer simple two-alternative questions. Each graph contained four data values; two were relevant to the question. Graphs were inspected for a mean of 15.5 s (SD 5.6). The first half was spent reading the question. Initial fixations on the graph focused on the legend and the X-axis in the attempt to locate relevant data. Legend and X-axis were re-fixated about 5 times each, even though one glance should have been sufficient. Fixations on data values became prominent during the third quarter of the trial, with preferences to fixate relevant data emerging during the final quarter. Fixations on the Y-axis occurred more often when the question required a decision about the value of the data, rather than ordinal comparisons. During the final seconds of the trial, fixations focused on the two alternatives of the question and either the legend or X-axis, depending on which corresponded to the alternatives. These results show that eye movement strategies evolve over time, reflecting a rational strategy to locate and then evaluate information. Early fixations focused on identifying the referents, and later fixations moved to evaluating the data, with the discrimination between relevant and irrelevant data emerging late. Frequent refixations may reflect attempts to conserve memory, as in visual tasks (Hayhoe & Ballard, 2005; Epelboim & Suppes, 2001). However, given the complexity of the cognitive decisions required to interpret graphs, the frequent re-fixations of critical locations, as well as the orderly progression of fixation preferences from referents to data, may support (and reveal) the gradual build-up of evidence that is used to generate the final interpretation of the graph.

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33.4083 Gaze patterns reveal how texts are remembered: A mental model of what was described is favoured over the text itself

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Several studies have reported that spontaneous eye movements occur when visuospatial information is recalled from memory. Such gazes closely reflect the content and spatial relations from the original scene layout (e.g., Johansson et al., 2012). However, when someone has originally read a scene description, the memory of the physical layout of the text itself might compete with the memory of the spatial arrangement of the described scene. The present study was designed to address this fundamental issue by having participants read scene descriptions that were manipulated to be either congruent or incongruent with the spatial layout of the text itself. 28 participants read and recalled three texts: (1) a scene description congruent with the spatial layout of the text; (2) a scene description incongruent with the spatial layout of the text; and (3) a control text without any spatial scene content. Recollection was performed orally while gazing at a blank screen. Results demonstrate that participants' gaze patterns during recall more closely reflect the spatial layout of the scene than the physical locations of the text. We conclude that participants formed a mental model that represented what was described, i.e., the spatial arrangement of the scene, which then guided the retrieval process. During their retellings, participants moved the eyes across the blank screen as if they saw the scene in front of them. Whereas previous studies on the involvement of eye movements in mental imagery tasks have used either spoken language or pictorial recollection task, our study is the first demonstration of the elicitation of mental imagery from text.

33.4084 Eye Movements During Rapid Naming tasks Predict Reading Ability.

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Rapid Automatized Naming (RAN) has long been known to identify poor/dyslexic readers. The mechanism underpinning RAN are often associated with phonological processing so we set out to determine to what extent eye movements contribute to RAN and text reading ability. Thirty typical readers and 18 poor readers (M age = 7.15), were assessed for phonological awareness, reading, and RAN. RAN was assessed while eye movements were being recorded. Poor/dyslexic readers demonstrated significantly longer fixation durations and more fixations per correctly named stimulus (defined as fixation efficiency). Fixation duration and fixation efficiency together were significant predictors of RAN (89%), reading accuracy (27%), reading comprehension (24%), and reading rate (33%), after controlling for phonological awareness and nonverbal intelligence (which together contributed 4%, 19%, 12%, and 2% respectively). Our results suggest that RAN is more closely related to fixation function than phonological skill and argue against the view that RAN is simply a measure of phonological processing. Rather, RAN should be conceptualised as a surrogate of the reading process including organized, sequential eye movements and selective shifts of attention, via accurate saccades and fixations between familiar objects of interest, requiring rapid icon identification and access to the lexicon for naming.

33.4085 Age-related changes in gaze dynamics during real-world navigation

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Healthy aging is associated with changes in the way people navigate in space. However, little is known about the impact of aging on eye movements mediating the exploration and acquisition of spatial information. This study investigated how aging shapes the oculomotor dynamics during goal-oriented navigation in real environments. Twenty young (μ=26 y/o, σ=5.06) and 20 old (μ=72 y/o, σ=4.22) subjects were ascertained to be healthy by visual, vestibular, oculomotor, and cognitive screening. Then, they were requested to solve a spatial navigation task by finding an invisible goal in a real environment (a 8.6x4.3 m street-like setup made of realistic relief sceneries). Subjects were disoriented at the beginning of each trial. After training (8 trials), the whole configuration of landmarks was rotated, creating a conflict between the landmarks and the geometry of the environment (5 probe trials). Eye and full body movements were recorded throughout the experiment. We found that older subjects took on average more time to reach the goal, due to a larger decision time during reorientation, suboptimal spatial navigation, and lower walking speed. Interestingly, compared to young subjects, a greater proportion of older adults reoriented according to a geometry-based strategy during probe tests, neglecting landmarks rotation. This came at a cost in terms of optimality of the trajectory employed. Gaze fixation characteristics (e.g., frequency, duration) as well as eyes/head coordination and general sensorimotor abilities did not differ with age. However, in older adults fixations were significantly more exploitative (looking at the same landmark) than explorative (searching for a new landmark). Also, older adults more often revisited previously fixated landmarks across a same trial. In conclusion, analyzing the time course of eye movement signatures in real-world spatial tasks helped unveiling and understanding age-related differences in spatial coding and goal-oriented navigation strategies.

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33.4086 Target presence affects the eye movement behaviour and kinematics of non-human primates in virtual navigation tasks

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As technology and scientific knowledge have advanced, the possibility and necessity of using virtual environments to run experiments has arrived, and the eye movements that are used to explore the environments need to be characterized. We trained two rhesus macaques to use a joystick to navigate in a virtual environment during a complex learning task and a foraging task. We analyzed gaze on screen behaviour and eye movement behaviours: saccades, fixations, and smooth pursuits. We also analysed the kinematics of saccades across the tasks and within periods of the Learning task. We found that gaze on screen as a function of the proportion of a trial changed based on whether there was a target currently in the environment. There was a median trial proportion of 47% when the subject was just navigating. When there were rewarded targets, the median gaze-on-screen was 80% and 91% for the Foraging and Learning tasks. For saccade kinematics, we calculated the main sequence by matching saccades on start location (< 5dva) and direction (< 10°) in bins of 3 dva amplitude. We ran repeated measures ANOVAs to test for differences and we fit a non-linear model to estimate the change in the main sequence. We did not find an effect of static vs dynamic phase of stimuli in the virtual environment. We did find that saccades were 7% faster when there were rewarded objects on the screen in virtual environments, and that the different levels of difficulty in our task did not alter the main sequence. There is likely an arousal change between simple virtual navigation and navigation towards a rewarded target, when the subject is more engaged in the task.

33.4087 Towards cognitive saliency: narrowing the gap to human performance

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Recently, computational models of saliency have achieved large breakthroughs in performance on standard saliency benchmarks (saliency.mit.edu). The top performers are artificial neural networks and consistently outperform traditional models. Some evaluation metrics have begun to saturate. This motivates the following questions: Have saliency models begun to converge on human performance? Where are people looking that saliency models are not? Using a collection of natural images from the MIT saliency benchmark with ground truth eye movements, we aggregated fixations on each image to create fixation maps. By thresholding these fixation maps, we obtained a set of highly-fixated image regions. We asked participants to label these regions (in the context of the full images) using one of two tasks: (1) selecting the tags that describe each region (e.g., face, text, animal, background, etc.), or (2) answering a set of binary questions about the region (e.g., "are any of the people in the image looking at something inside the highlighted region?"). We used the crowdsourcing platform Amazon's Mechanical Turk to collect a fixed set of labels per region. To provide the first direct quantitative analysis of model mistakes, we evaluated whether saliency models made predictions in each type of region. Our analysis revealed that the best neural network models miss the same regions: including objects of gaze, locations of implied action or motion, important text regions, and unusual elements. We quantified up to 60% of the remaining model errors. To continue to approach human-level performance, we argue that saliency models will need to reason about the relative importance of image regions, such as focusing on the most important person in the room or the most informative sign on the road. More accurately tracking performance on saliency benchmarks will require finer-grained evaluations and metrics. Pushing performance further will require higher-level image understanding.

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33.4088 CHAP: An Open Source Software for Processing and Analyzing Pupillometry Data

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Pupil dilation is an effective indicator of cognitive load. There are many available eye tracker systems in the market that provide effective solutions for pupil dilation measurement, which can be used to assess different cognitive and affective processes. However, there is a lack of tools for processing and analyzing the data provided by these systems. For this reason, we developed CHAP - an open source software written in Matlab. This software provides a user-friendly interface (graphical user interface) for processing and analyzing pupillometry data. The software receives input of a standard output file from the Eyelink (EDF file) and the Eyetribe (CSV file) eye trackers and provides both pre-processing and initial analysis of the data. Our software creates uniform conventions for building and analyzing pupillometry experiments, and provides a quick and easy-to-implement solution for researchers interested in pupillometry.

33.4089 Dangerous Ambiguity: Capturing Shooter Bias with an Eye Tracker

Glen Gagnon[1], Chad Peltier[1], David Johnson[1], Mark Becker[1]; [1]Michigan State University

When making rapid, uncertain decisions about danger, categorical heuristics are utilized to process visual information. In particular, race and racial stereotypes influence visual perception, impacting accuracy and reaction times. This research aims to clarify what sources of information a person uses in making decisions about danger. Our study examines stereotypic vision as an extension of Correll et al.'s (2015) work on how participants use racial information to process ambiguous visual stimuli. Participants completed a first-person-shooter task in which they made rapid decisions (shoot or don't shoot) for Black and White targets holding either a gun or harmless object. While participants viewed images in quick succession, an eye tracker collected data on eye movements relative to two interest areas: the target's face and the object in the target's hand. In alignment with the previous literature, we discovered that reaction times and error rates signal stereotypic racial bias. Responses for Black targets have higher error rates, faster reaction times for gun trials, and slower reaction times for non-gun trials. Moreover, additional eye tracking measures, beyond the viewing angle proposed by Correll et al., provide insight into how participants gathered information. Overall, we found that participants relied on ambiguous information to make decisions for stereotypic targets and sought more certainty for counter-stereotypic targets. When viewed collectively, our data supports Correll's findings of stereotypic influence. Measures of dwell time

and refixations on faces and guns suggest initial fixations are more ambiguous for Black targets. However, subsequent fixations become more explicit, mitigating racial bias in several contexts

33.4090 **Eye Movements during Emotional Scene Processing: Exploring the Role of Visual Perception in Intrusive Mental Imagery** Stephanie Roldan[1](sroldan08@vt.edu), Olivia Obertello[1,2], Anthony Cate[1,3]; [1]Psychology Department, College of Science, Virginia Tech, [2]Department of Human Nutrition, Foods and Exercise, College of Agriculture and Life Sciences, Virginia Tech, [3]Center for Human-Computer Interaction, Virginia Tech

Persistent re-experiencing of involuntary mental images is a hallmark characteristic of several psychopathological disorders, including posttraumatic stress disorder, obsessive compulsive disorder, depression, and schizophrenia. This study uses the established link between eye movements and visual processes to investigate healthy cognitive processes during both perceptual search and mental recreation of negative valence, high arousal scenes. Non-clinical subjects, with no history of mental illness or previous trauma, viewed 40 photographic scenes selected from the International Affective Picture System (IAPS). Stimuli chosen for this experiment were rated by the IAPS to have either negative valence with high arousal or neutral valence with low arousal. An infrared eye tracker recorded spontaneous eye movements while 20 scenes from each emotional category were presented in blocks of 5 on a digital monitor. Scene presentations (5 s) were preceded by a fixation cross (6 s) and followed by a pleasantness rating prompt (1-5). After a brief fixation period (12 s), participants were prompted to imagine the preceding scene on a blank gray screen (5 s), followed by a rating of imagery vividness (1-5). Average fixation count toward the central one half and outer one half of the image were compared across emotional and viewing/imagining task conditions. Results revealed a significantly greater amount of average fixations to peripheral over central areas of interest (AOIs) in both emotional conditions ($p = 0.0132$). However, the discrepancy in fixations directed toward central and peripheral regions was significantly greater during imagining of negative scenes ($p < .0001$) than in any other condition. We hypothesize that this task-specific effect reflects cognitive processes underlying the formation of mental images which lend themselves to intrusive and involuntary re-experiencing. These results may be used to improve future behavioral interventions designed to reduce flashback symptoms in patients.

33.4091 **The importance of gaze coherence of CCTV operators in facilitating the ability to recognise harmful intentions** Greta Todorova[1](2028282t@student.gla.ac.uk), Joseph Burling[2], Hongjing Lu[2], Frank Pollick[1]; [1]School of Psychology, University of Glasgow, [2]Psychology Department, University of California, Los Angeles

Experienced CCTV operators are better at predicting violent behaviour than novices. It has been suggested that experienced, trained operators acquire gaze strategies to process complex visual scenes more efficiently. We examined whether the coherence of the gaze path of an operator aids in perceiving harmful intent and how this compares to the situation when coherence is altered but spatial location information is retained. To achieve this, we obtained 18 real-life surveillance videos, 16-seconds each, grouped in three categories ('fight', 'confrontation', 'play'). 'Fight' and 'confrontation' videos included aggressive behaviour, but only 'fight' videos resulted in a violent outcome (after the video ended). 'Play' videos portrayed playful behaviour without the involvement of violence. For each video, we used eye-movement data from experienced CCTV operators who successfully predicated harmful intent above chance. Naïve participants then viewed a filtered version of each video by overlaying a high resolution foveal window with a blurred periphery. Videos were filtered according to an intact gaze path from one operator or shuffled gaze locations from two operators. The shuffled gaze path was computed by alternating the two operator's eye-coordinates every 0.33 seconds. Participants viewed processed videos in both intact and shuffled conditions in two blocks. For each video, they rated the likelihood of a violent incident occurring after the video ended based on a 6-point scale. Preliminary results indicate that ratings of violent outcome are significantly greater when viewing the videos processed with the intact gaze patterns than with the shuffled gaze patterns, particularly in 'fight' and 'play' videos. This suggests that the gaze path coherence aids in perception of intent and that the spatial locations of fixations are less informative in guiding performance. Therefore, allowing novices to follow the learned gaze strategies of operators may provide effective training in improving their ability to recognise harmful intentions.

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33.4092 **You lookin' at me? Perception of a real-time dyadic interaction influences gaze behavior** Michael Kleiman[1](mjkleiman@gmail.com), Elan Barenholtz[1]; [1]Florida Atlantic University

Previous studies have found that gaze behavior tends to be directed towards either the eyes or mouth of a talking face, depending on the situational context and task demands. However, these previous studies may not be representative of natural social interactions due to the participants' knowledge that they are watching pre-recorded videos, and as a result may not translate to real-time interpersonal communication. Here, we examined fixation behavior for when participants believed that they were engaging in a real-time dyadic interaction and compared this to when they were aware that they were watching a pre-recorded video. We used four video sequences of two actors (one male and one female) reading two lectures each. Each participant was shown two videos: one ('Real-time' condition) utilized deception to encourage observers to believe that they were interacting with a live person who was able to see and hear them through online remote video communication, and the other ('Pre-recorded' condition) contained only the lecture portion of the video with observers informed that they were watching a previously recorded video. We found a highly significant tendency of participants to gaze away from the face periodically when they believed they were engaging in a real-time interaction, resulting in significantly less time spent attending to the face compared to the Pre-recorded condition. In addition, we found that when participants were fixated on the face, they fixated the mouth at a higher proportion of time in the Pre-recorded condition vs. the Real-time condition. The findings suggest that the belief that an interlocutor can see you influences fixation behavior and suggests that previous studies that examine social gaze behavior may lack ecological validity.

SCENE PERCEPTION: CATEGORIZATION AND MEMORY

Sunday, May 21, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.4093 **The emotional valence of scene ensembles is less extreme than its constituents** Chloe Burkhead[1](burcr-18@rhodes.edu), Jason Haberman[1]; [1]Department of Psychology, Rhodes College

The visual system extracts summary statistics from crowds of similar items. This heuristic, known as ensemble perception, works across multiple visual domains ranging from low-level features such as size, shape, and orientation to high-level objects such as faces, biological motion, and animacy. In the current study, we examine how observers represent the emotional valence of a complex group of scenes. In a pilot experiment observers evaluated the emotional valence of several hundred scenes on a scale ranging from ±5. From these, a total of 190 scenes were selected that spanned the full range of emotional ratings (and had an equal number of positively and negatively rated images). Scenes included pictures of people grocery shopping, working, cooking, etc. Observers were first asked to rate the emotional valence of each scene, and then subsequently rate the average emotional valence of randomly assembled groups of four scenes. Results indicate that there is significant compression of the ensemble ratings relative to the expected rating based on the individual images (i.e., ensembles, regardless of their overall valence, were viewed as less extreme than the individual ratings would predict). These results are surprising for two reasons: 1) they demonstrate ensemble representations for abstract scene information and 2) they contrast with other work suggesting that ensemble ratings for certain objects are amplified relative to individual ratings (e.g., Harp, Haberman, & Whitney, VSS poster, 2009).

33.4094 **Representations of emotional scenes during memory retrieval** Doyoung Park[1](park.doyoung@kaist.ac.kr), Sue-Hyun Lee[1,2]; [1]Department of Bio and Brain Engineering, College of Engineering, Korea Advanced Institute of Science and Technology (KAIST), [2]Program of Brain and Cognitive Engineering, College of Engineering, Korea Advanced Institute of Science and Technology (KAIST)

Sunday PM

The retrieval of emotional scene is a critical faculty for our survival in the real world. Especially, retrieval of scenes that are relevant to negative emotions can help you deal with dangerous situations. However, it remains unclear how emotional scenes are represented in the cortical areas during retrieval compared to neutral scenes. To investigate representations of emotional (negative) or neutral scenes during retrieval, here we performed an event-related functional magnetic resonance imaging (fMRI) experiment. Prior to scanning, participants were trained to memorize the pseudoword-scene associations. Every participant showed good performance (>99% correct) in the forced-choice tests after training, indicating accurate retrieval of scene information. In addition, the subjective vividness rating showed comparable scores between retrieved negative scenes and neutral scenes. During scanning, participants were presented with perception and retrieval trials. We focused on the response patterns of scene-selective visual areas: PPA (parahippocampal place area), OPA (occipital place area), and RSC (retrosplenial cortex). Using multivoxel pattern analyses, we found that PPA showed more discriminable patterns of response to individual negative scenes during retrieval compared to those elicited during retrieval of individual neutral scenes, whereas other scene-selective areas showed little impact of emotion on the discrimination. These results suggest that negative emotion generates more discriminative neural responses for individual scenes especially in PPA during retrieval. This work was supported by a grant of the Korea Health Technology R&D Project through the Korea Health Industry Development Institute (KHIDI) funded by the Ministry of Health & Welfare, Republic of Korea (HI15C3175), and the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (2016R1C1B2010726).

Acknowledgement: This work was supported by a grant of the Korea Health Technology R&D Project through the Korea Health Industry Development Institute (KHIDI) funded by the Ministry of Health & Welfare, Republic of Korea (HI15C3175), and the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (2016R1C1B2010726).

33.4095 **Scene's Openness Revisited: What You See vs. Where You are** Soojin Park[1](park@cogsci.jhu.edu), Thitaporn Chaisilprungraung[1], Ruu Harn Cheng[1]; [1]Department of Cognitive Science, Johns Hopkins University

Scene understanding is a vital part of human's ability to function in the real world. A prominent question in scene perception research asks which aspect of scene information is being represented in different scene-selective regions. One prominent view holds that the parahippocampal place area (PPA) represents a scene's spatial layout or how open or closed a scene is. Another recent view suggests that this area encodes the low-level spatial frequency of scene images. Here we examined a third possibility: the actual location of an observer relative to a scene. This last possibility draws on an observation that a scene with an open spatial layout such as a beach when viewed from inside a room may indeed be considered closed, due to the closedness of an interior space that surrounds the observer. In this experiment, we attempted to tease apart the three possibilities by studying patterns of neural responses to different scene types varying in their level of image energy, spatial layout, and location of observers. In an fMRI block-designed experiment with one-back repetition task, participants passively viewed three types of scene images: 'inside-open' (i.e., open spatial layout scenes viewed from an inside), 'inside-closed' (i.e., closed spatial layout scenes viewed from inside), and 'outside-open' (i.e., open spatial layout scenes viewed from outside). We carefully chose all image stimuli such that the difference in the level of image energy reflected the distinction between the scene's open vs. closed layout but not inside vs outside location. Thus, under the image energy and the spatial layout hypothesis, scene-selective regions are expected to be more sensitive to the layout distinction than the observer's location distinction. The reverse pattern is true under the observer's location hypothesis. To anticipate, our preliminary MVPA results support the latter, suggesting the significance of the observer's location information in scene processing.

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33.4096 **Behavioral relevance impacts utilization of diagnostic information for scene categorization at multiple time windows: Electrophysiological evidence** Natalie Hansen[1](natalie.hansen@wright.edu), Birken Noesen[1], Assaf Harel[1]; [1]Psychology, Wright State University

Recent work aimed at uncovering the temporal dynamics of scene processing (Harel et al., 2016) has found that global scene properties modulate the amplitude of early ERP components. Key among these is the P2, peaking 220ms post-stimulus onset, which is sensitive to both the naturalness of the scene and its spatial boundary. It is still not clear, however, how much these ERP signatures are impacted by observer-based goals, such as task context, or whether they reflect automatic, stimulus-driven processing of scene information. To address this question, we investigated how task context impacts the electrophysiological responses to global scene properties. Participants viewed 96 scene images while their ERPs were recorded. The scenes spanned two dimensions: naturalness (manmade/natural) and spatial boundary (open/close). In half of the trials the participants determined whether the scene was manmade or natural (naturalness task), and in the other half whether it was open or closed (spatial boundary task). Thus, one scene dimension was task-relevant in half of the trials but task-irrelevant in the others. We found that the P2 amplitude could distinguish between open and closed scenes and between manmade and natural scenes, independently of whether the participants were attending to the relevant dimension or not. However, P2 amplitude was higher in the spatial boundary task than in the naturalness task across all scene dimensions. This could not be attributed to task-difficulty, as response times in both tasks were equivalent. A significant effect of task context on scene properties was found earlier, at the P1 level. P1 amplitude varied as a function of spatial boundary, but only in the spatial boundary task. When participants viewed the same images but attended their naturalness, this effect dissipated. These findings highlight the temporal dynamics of task-specific and stimulus-driven utilization of diagnostic scene information underlying human scene categorization.

33.4097 **Visual, Functional, and Semantic Contributions to Scene Categorization** Michelle Greene[1](mrgreene@stanford.edu), Bruce Hansen[2]; [1]Department of Computer Science, Stanford University, Stanford CA, [2]Department of Psychology & Neuroscience Program, Colgate University, Hamilton NY

A hallmark of human visual understanding is the remarkable speed with which we categorize novel scenes. Previous work has demonstrated that scenes can be categorized via a number of different features including low- to mid-level visual features (e.g. Groen et al., 2012; Hansen & Loschky, 2013; Walther & Shen, 2013); objects (Greene, 2013); spatial layout (Greene & Oliva, 2009); and a scene's functions (Greene et al., 2016). We do not yet have a full understanding of the temporal dynamics underlying the processing of these features. These dynamics place strong constraints on the mechanisms of rapid scene categorization. However, these feature spaces are not independent, which makes investigating the independent contributions of each feature space challenging. Using a model-based approach, we examined the shared variance of several feature spaces within a single comprehensive investigation. Participants (n = 13) viewed 2,250 full-color scene images (matched for luminance and color contrast) drawn from 30 different categories while having their brain activity measured through 256-channel EEG. We examined the variance explained at the each electrode and time point of ERP data from 14 different computational models: eight layers of a convolutional neural network (CNN), low-level visual features including LAB color histograms, a V1-like wavelet representation, and GIST descriptors; a bag of words model of objects; a lexical distance model; and a model of functions obtained by crowdsourcing. A maximum of 26% of the ERP variance could be explained by the 14 models. Information from low-level visual features was available earliest (50-95 msec), while later layers of CNN were available later (150-250 msec). Interestingly, information about functions was available relatively late (387 msec) and was maximal over frontal electrodes. Given its unique time course and topography, scene functions appear to represent a feature space that is neither exclusively visual nor semantic.

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Sunday AM

33.4098 Processing global properties in scene categorization

Hanshu Zhang[1](zhang.180@wright.edu), Joseph Houpt[1]; [1]Department of Psychology, Wright State University

Existing research demonstrates the important role of global scene properties in early visual processing. However, it is unknown how global properties interact during the processing. In the current study, we examine categorization performance on two global property scales, "natural – manmade" and "open – closed." To balance the extent to which scenes exemplified characteristics across the scales, we ran an experiment on Amazon Mechanical Turk (AMT) to estimate latent rankings for each scale. In this experiment, a participant was shown two randomly selected photographs drawn from a subset of the Scene Understanding Database and asked to report which exemplified the characteristic better, e.g., "Which scene is more natural." These judgements were then used to estimate the rankings using the Bradley-Terry model. In our main experiment, subjects were required to categorize scene images in three different blocks: natural/manmade; open/closed; and "natural and open"/"manmade or closed". Participants in this experiment had relatively consistent choice probabilities with the AMT rankings when discriminating natural/manmade scene images. However, participants tended to categorize natural-closed images as open in the open/close block. Consistent with this judgement, participants frequently categorized natural-closed images as "natural and open" in the "natural and open" block. To examine whether people were more efficient at determining "natural" and "open" together than separately, we used a baseline independent, parallel, exhaustive processing model. To estimate the baseline, we used response times from the natural/manmade block and the open/closed block. All participants were more efficient than predicted by the baseline model in the "natural and open." Because "natural" and "open" are highly correlated in the ranking scales, subjects may only do "natural/manmade" discrimination when asked to categorize "natural and open" images. This resulted in their highly efficient performance in the "natural and open" block.

Acknowledgement: AFOSR

33.4099 Category in temporal context cues scene integration

Robert Wiley[1](wiley@cogsci.jhu.edu), Soojin Park[1]; [1]Johns Hopkins University

Previous work has shown that retrosplenial cortex (RSC) is implicated in scene integration of multiple views. The current research investigates the role of category information in scene integration and its behavioral consequences. Using statistical regularities in temporal context, we have shown that RSC responds significantly greater to a repeated scene exemplar if the preceding context provides information about a scene category (VSS 2016). For example, upon presenting an image sequence of MountainA-WaterfallA-BeachA, and later MountainB-WaterfallB-BeachA (category-context condition), RSC responds significantly greater to the repetition of BeachA. This effect was not present when the temporal context didn't contain repeated category information (novel-context condition, e.g. MountainA-WaterfallA-BeachA and DesertA-ForestA-BeachA). Here we test two possible interpretations of the above result using fMRI and behavioral experiments. In the first experiment, we test whether the repetition enhancement of RSC is due to a carryover effect from the preceding context. When we replaced the third item (e.g., BeachA with BeachB) while keeping preceding context the same (e.g., Mountain-Waterfall), RSC no longer showed greater activation for the third item, suggesting that this was not due to carryover. In the second experiment, we hypothesize that if category information in temporal contexts work as a cue for integration, then different scene images that were grouped in temporal context should be judged as more similar to each other. In a behavioral experiment (N=23), participants were exposed to images in one of two conditions while performing an indoor-outdoor decision task: Category-context or Novel-context conditions. Afterwards, they were given a surprise same-different task on pairs of images (e.g., MountainA vs MountainB). We found that participants in the Category-context condition were significantly slower to respond "different" to the pair than participants in the Novel-context condition. This finding indicates that perceptual similarity of scenes increases when they are grouped within the same temporal context.

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33.4100 Perceptual properties of scenes determine their subsequent memory

Assaf Harel[1](assaf.harel@wright.edu), Emily Artz[1]; [1]Department of Psychology, Wright State University

Recent years have seen an advent of research on the perception of visual scenes; however, much less is known about how scenes as a unique category are memorized, particularly regarding the relationship between long-term memory of scenes and their perceptual encoding. In order to address this question, we conducted a study to determine whether global image properties found to be diagnostic for the perception of scenes will also be useful for successful memory recognition of the same scenes. The study consisted of two phases: a study phase and a test phase. In the study phase, participants were presented with 96 scene images varying along two dimensions: spatial boundary (closed and open scenes) and naturalness (manmade and natural scenes). In the test phase, participants were presented with the same 96 scenes embedded along a new set of 96 images, which spanned the same dimensions as the studied images, and overall were highly similar to the original stimulus set. The participants were asked to indicate which scenes were presented to them in the study phase, and which were new scenes. We found that across varying stimulus presentation rates, recognition performance significantly varied as a function of the naturalness of the scenes, with man-made scenes better remembered than natural scenes. An image-based computational analysis of the memorability of the scene images revealed that the manmade and natural scenes did not differ in their memorability and that the majority of scenes used in our study were of low to medium memorability, indicating the current results are not likely to be explained by individual image-based memorability. We suggest that the current findings emphasize a close correspondence between the perception of scenes, exemplified in their global scene properties, and their subsequent memory.

33.4101 Remembering overlapping scenes: higher false alarm rates for unseen parts of scenes

Filip Dechterenko[1](dechterenko@praha.psu.cas.cz), Jiri Lukavsky[1]; [1]Institute of Psychology, Czech Academy of Sciences

Our visual experience is continuous; we do not see individual images and the remembered views overlap. We are able to remember large amount of individual scenes with high accuracy and low false alarm rates (Konkle et. al, 2010). Here, we studied how recognition accuracy changes with repeated presentation of identical vs overlapping scenes. We selected images and divided each into three segments. Our stimuli consisted of two adjacent segments - thus we could present one image twice or present two images sharing 50% of the area. We showed for 220 images each for 3 s. We either presented images once (110 images), as two identical views (55x) or two overlapping views (55x). To assess working memory performance, we asked subjects after each 5 trials whether they have seen an image patch (43% x 43%). The patches were selected from the 1) presented views, 2) unseen views from the remaining image segment, 3) could be distractors. After the experiment, we tested the recognition of the patches from the views seen twice (2x patches), once (1x), from unseen views (0x) and from the new images (distractors). Results (28 subjects) showed that in the working memory test, subjects were able to recognize patches from the presented images (percentage correct: 73%) and identify distractors (false alarm, FA 19%), but they showed high FA rate for unseen parts (41%). For the long term memory, the recognition increased with repeated presentation (2x patches: 69%, 1x patches: 58%). The FA rate was higher (41%). People struggled to identify the patches from unseen parts (FA 49%). The results showed that while people can learn a large number of photographs, they have difficulties when queried about images coming from the unseen part of same scene. The visual and semantic similarity together with photography style are likely factors behind this effect.

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33.4102 Scene categorisation in the presence of a distractor

Jiri Lukavsky[1](lukavsky@praha.psu.cas.cz), Filip Dechterenko[1], Andrea Dally[2]; [1]Institute of Psychology, Czech Academy of Sciences, Prague, [2]Faculty of Education, Charles University, Prague

People can recognize the content of a real-world scene (gist) within a single fixation. This ability is not limited to the central vision. Larson et al. (2014) showed how retinal eccentricity affects the time course of the gist acquisition. Here, we tested how allocating attention affects gist acquisition in central vision and in periphery. We presented participants with compos-

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ite images featuring one scene circularly cropped in the center (radius 5.54 deg) and another in surrounding ring (radius 11.8 deg). The participants' task was to pay attention to either a center or periphery (varied across blocks) and decide whether the scene presented there was a natural or man-made scene. The stimulus was shown for 33 ms, followed by 167 ms ISI and 33 ms pixel mask. We used eye tracker to check that the central fixation was maintained throughout a trial. Each of 28 participants completed 100 central and 100 peripheral trials. Participants were successful in categorizing scenes (accuracy 96.5%). The categorizing natural scenes was easier (98.2% vs 94.9%). We found no difference in accuracy when categorizing scenes in fovea/periphery (97.0% vs 96.0%). The concurrent presence of incongruent scenes led to a small but significant drop in accuracy (96.9% to 96.1%). As an indirect measure of confidence, we analyzed the response times. Participants responded to natural scenes significantly faster (445 ms vs 527 ms), but neither allocation of attention (center: 466 ms, periphery: 507 ms) or presence of scene conflict (conflict: 475 ms, congruent: 497 ms) had a significant effect. We found that in this particular settings people were able to successfully categorize both central and peripheral parts of the composite scenes. The presence of the conflict did not affect the performance suggesting that the other scene is successfully suppressed

Acknowledgement: Czech Science Foundation (16-07983S)

33.4103 Narrative priming of scene gist: The role of sequential expectations in scene gist perception Maverick Smith[1](ms1434@ksu.edu), John Hutson[2], Thomas Hinkel[3], Kaydee Tran[4], Megan Steele[5], Lester Loschky[6]; [1]Kansas State University

Observers can categorize a novel scene within the first 100 ms of its onset. Researchers have suggested this is accomplished through a rapid feed-forward sweep of neural activation. Consequently, researchers have focused on examining the minimal perceptual information diagnostic of a scene's semantic category, rather than investigating the role that top-down processes play in rapid scene categorization. Thus, most scene gist studies present scenes from multiple categories in randomized sequences.Conversely, in this experiment, we tested whether scene gist recognition is facilitated by sequential expectations.To do this, we created more ecologically valid spatio-temporal "narrative" sequences of images along spatially connected routes from starting points to destinations (e.g., office, hallway, stairwell, sidewalk, parking lot). Scene images were presented one-at-a-time, and based on pilot-testing, briefly flashed (24 ms) and masked (48 ms), followed by selecting the scene category from an 8-AFC array. To reduce predictability of subsequent images, we included subsequences of randomly 1-4 scenes from each category (e.g., 1-4 office images followed by 1-4 hallways, etc.). Critically, scenes were shown in either coherent or randomized narrative sequences to test two competing alternative hypotheses: 1) "Narrative coherence": accuracy is higher for images in coherent narrative sequences because scene category expectations prime representations for to-be-presented scenes; 2) "Feed-forward": accuracy does not differ between coherent and randomized image sequences because it is a purely feed-forward process. Results: images presented in randomized sequences were categorized just as accurately as images presented in coherent sequences, consistent with the "Feed-forward" hypothesis. Furthermore, accuracy did not increase as a function of the number of sequential exposures to a single scene category (e.g., 1-4 office images in a row), suggesting that the mechanisms responsible for perceiving a scene's meaning are so rapid that prior exposures do not support extracting the gist of subsequent scenes.

33.4104 Through the door: Boundary Extension of areas viewed through scene-intrinsic apertures Carmela Gottesman[1](cvgottesman@sc.edu); [1]University of South Carolina Salkehatchie

Picture memory consistently indicate that viewers extend their mental representations to include areas of the scene that were not visible in the partial view presented in the picture. This "boundary extension" can provide useful predictions regarding the layout of areas of the scene that are not visually available at a given moment. The current study tested whether people extend the boundaries of areas seen through scene-intrinsic apertures such as doors, pathways, and windows. Participants viewed sixteen scenes that included such an apertures, with another scene visible through it. For example, a picture showed a hallway ("external scene") with the front door open showing the front yard ("internal scene"). These pictures were intermixed with other pictures of scenes showing no such combinations. To ensure that viewers played attention to the "internal scene", participants were asked to indicate whether the scene was an indoor, outdoor, or a combination scene (like the example above). After the presentation, viewers were asked to select the version of the picture they remember from four possible versions. Given the robustness of Boundary Extension, the exact target picture was not available. Rather, the four choices included the following: an overall extended version (a typical extended version with no extension of the "internal scene"), a version where only the "internal scene" was extended, a version where only the "external scene" was extended (resulting in a restriction of the "internal scene") and a version where both the internal and the external scenes were extended differentially. Results indicated Boundary Extension of views seen through the aperture as participants selected the versions with the extended "internal scenes" more often than the versions where only the picture boundaries were extended. This extension for naturally occurring boundaries rather than just arbitrarily imposed picture boundaries speaks to the everyday use of such layout extrapolations.

33.4105 Visualizing the Percept of a Scene John Defant[1](johndefant@mail.usf.edu), Thomas Sanocki[1], Steven Schultz[1], Trang Nguyen[1]; [1]Psychology Department, University of South Florida

Scene perception is a powerful, remarkable process that handles an immense variety of possible scenes efficiently. But the question of "what people see" remains largely unanswered. What do people see in a briefly presented, novel but high-integrity scene? How does the percept change across individuals? And can the percept be primed by general abstract concepts or by repetitions of words? The present research extends a full report method in which observers make a written report of what they saw in a briefly presented, novel scene. There were two critical scenes, each involving a mixture of people-related and structure-related content. Overall, the written reports were perceptually accurate, with high hit rates for content unique to the scenes and few inaccuracies. The priming manipulation was that, before the two critical scenes, observers saw scenes containing either people or structural content. The priming manipulation increased reports of prime-consistent details. We use these results to create scene percepts: Descriptions of what people saw in the scene. Most of the descriptions fall into a people-activity-structure schema. The major effect of priming was to increase the amount of structure-related information reported by the structure-primed group. People information was similar in absolute amounts between priming groups, suggesting that there is a more absolute priority for people information. Further analyses quantify how much of the priming was due to repetition of particular words versus abstract concepts.

SCENE PERCEPTION: SPATIOTEMPORAL FACTORS

Sunday, May 21, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.4106 Seeing the road in the blink of an eye - rapid perception of the driver's visual environment Benjamin Wolfe[1,2](bwolfe@mit.edu), Lex Fridman[2], Anna Kosovicheva[3], Bryan Reimer[2], Ruth Rosenholtz[4]; [1]CSAIL, Massachusetts Institute of Technology, [2]AgeLab, Massachusetts Institute of Technology, [3]Department of Psychology, Northeastern University, [4]Brain and Cognitive Sciences, Massachusetts Institute of Technology

Natural scenes can be perceived in considerable detail with short stimulus durations. However, research on this has focused on static images, rather than dynamic video of the natural world. The ability to perceive the world quickly is particularly important in the context of driving, since in 400 ms a car going 65 mph (105kph) moves 40 feet (12 meters). To assess how quickly subjects can get the gist of a road scene, we used a scene prediction task where subjects were shown a short clip, followed by two still images. Subjects were shown two stills taken from the video following the clip and asked which of the two stills would come first. The clips ranged in length from 100 to 4000 ms. The pair of still images were taken from a minimum of 500 ms after the end of the clip, and were separated by 100 to 4000 ms. In addition, we performed a control experiment in which subjects were asked to discriminate which still frame came first without first viewing any video. In the control task, without any video, subjects achieved 70% accuracy, but this did not change as a function of separation between the still images. When subjects were shown a short clip prior to making their judgment, performance improved modestly (to 80%). However, a pattern emerged in which brief clips facilitated discrimination of the still images, with the effect being most pronounced for widely separated still images, indicating that the dynamic information was useful even with short clip durations. While one would not want to rely on such brief views of the world for driving, these results indicate that information about dynamic scenes – their gist – is available on a similar time course as the gist of static scenes.

33.4107 Event Model Construction Occurs Within a Single Eye Fixation

Adam Larson[1](larson@findlay.edu), Taylor Simonson[1], Martin McMullen[1], Karissa Payne[1]; [1]Department of Psychology, The University of Findlay

Research has shown that event models, a working memory mental representation of actions, are constructed and can be used to predict future actions (Zacks, Kurby, Eisenberg, & Haroutunian, 2011). Although event model construction has been hypothesized, we still know little about its time-course. Namely, how long does it take to construct an event model? Previous research has indicated scene and action categorization may form the basis of an event model (Larson, Hendry, & Loshcky, 2013). If so, then recognizing the scene category (e.g., Park) would prime scene categorization for a subsequently presented scene image. Conversely, some research has shown that top-down knowledge does not aid scene categorization (Potter, Wyble, Hagmann, & McCourt, 2013). If so, then priming would not be observed. Four scene categories were used (Park, Yard, Office, and Kitchen). Participants were presented with 192 trials. A trial presented a variable duration prime image (106, 188, 353, 1024, 2025, or 4026 ms) followed by a target scene image for 47 ms and then a cue word. Participants were instructed to determine if the cue word matched the target. Half of the trials were validly cued, requiring a yes response, whereas the remaining were invalidly cued, requiring a no response. Half the trials presented prime and target images from the same scene category, whereas the remaining trials presented prime and targets from different scene categories. Results show evidence of positive priming when the prime was presented for 188 ms. However, negative priming was found for primes presented for 2025 ms. This suggests that event model construction occurs rapidly and aids scene categorization for subsequent scene images. However, this benefit is limited to a time-course representative of a single eye fixation.

33.4108 Peripheral involvement of the extraction of the gist of the scene.

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Human observers are capable to rapidly extract spatial information to get a sense of their environment as well as its functional potential. This phenomenon is called the gist of the scene, and in this study, we aimed to create a task to explore it in patients with homonymous visual field defects. It is thought that the gist of the scene is derived from networks with larger-sized receptive fields. And indeed previous work showed that the peripheral visual field, which is tuned to the lower spatial frequencies, is most useful for the scene gist extraction. However, the images only extended to 20o and the content of the scene information was depending on foveal or peripheral presentation. In our study, 15 healthy participants were piloted on a two-alternative forced choice, discriminating scenes presented for 150 ms. They made this discrimination based on either basic-level features (ocean vs field) or global-level features (man-made vs natural and concealment). All images had identical mean contrast and luminance and the signal-to-noise ratio was systematically manipulated with pink noise. We assessed two conditions: foveal presentation where the scene was compressed in the central 12o and peripheral presentation where the scene was presented at 40o while occluding the central 12o. Proportion correct increased significantly more with signal-to-noise ratio when presented peripheral than foveal. This indicates that the periphery is more robust to noise than foveal vision. However, this effect was less pronounced for ocean vs field than both global-level discriminations and for concealment than for naturalness. This can be accounted for by general difficulty of the discrimination tasks. In conclusion, we validated an objective measurement of peripheral involvement in gist recognition. This task will give us the possibility to further explore the peripheral gist extraction in patients that suffer from visual field defects.

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33.4109 Spatial frequency tuning for indoor scene categorization

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Indoor scenes typically contain a wealth of cues that are potentially useful for recognition, including characteristic global spatial properties and objects contained in the scene. Which of these cues do people actually use for accurate and quick scene categorization? Here we investigated this question in the spatial frequency (SF) domain. Using the SF Bubbles technique (Willenbockel et al., 2010), we examined which SFs are significantly correlated with observers' RTs in a scene categorization task with four categories — bathroom, bedroom, kitchen, and office. The base stimuli consisted of 800 gray-scale photographs (256 x 256 pixels) equated in luminance histograms and rated as typical exemplars of the respective category. They were SF filtered trial-by-trial using 20 randomly distributed Gaussian "bubbles" with a standard deviation of 1.8. The stimuli were presented in random order at a visual angle of 6 degrees and remained on the screen until the observer's response. Observers were instructed to press the space bar as soon as they recognized the scene category and, upon stimulus offset, press the respective key for the correct category. Feedback was provided after each trial. Mean accuracy across observers was 88.16% correct; mean RT was 486 ms. RTs did not differ significantly between categories. A multiple linear regression on the transformed RTs from correct trials and the respective SF filters revealed two SF bands significantly linked with fast responses: one around 3 cycles per image (cpi) and one around 28 cpi (octave width about 1). Interestingly, the latter SF band overlaps with the SFs found to be correlated with fast and accurate object recognition (Caplette et al., 2014). Our results suggest that people use a combination of the scene gist conveyed by low SFs and object information conveyed by a narrow band of relatively high SFs for effectively recognizing complex indoor scenes.

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33.4110 I couldn't help but notice: Irrelevant object-scene inconsistencies influence search for highly visible gabor patches

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The fact that we perform many searches through naturalistic scenes very efficiently on a daily basis suggests that object and scene identification (as well as their integration) require little attentional resources and might be obligatory in the sense that they are hard to suppress. Does obligatory scene processing also affect a purely perceptual task like gabor identification? Objects that do not fit the semantics of the scene (e.g. a toothbrush in an office) are typically fixated longer and more often than consistent controls. Here we overlaid a grid of gabor patches on a background scene that was irrelevant to the task of searching for a target gabor with a perfectly horizontal or vertical orientation. Some of the background images contained semantically inconsistent objects. To maximize their conspicuity gabors were outlined with a red box for easy saccadic targeting, thus avoiding the need to search through the background scene. Once fixated, figure-ground segmentation of the gabors on their gray background should be equally difficult for each element. For part of the irrelevant background scenes the target was overlaid on the critical object, whereas in other scenes the target was placed elsewhere and a distractor took its place on the object. Although time to first target fixation and RTs seemed unaffected by target placement or object consistency, analysis showed that participants looked longer at distractors placed on top of a semantically inconsistent object. Participants were also more likely to misjudge the target when a semantically inconsistent object was present in the scene. Replicating previous findings (Cornelissen & Vo, 2016) that scene and object identities are processed obligatorily and influence ongoing gaze behavior, we now extend these findings by ensuring high conspicuity and using only target present trials, while nevertheless showing that a purely perceptual task can be influenced by irrelevant background semantics.

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33.4111 Pupil size is sensitive to dynamic change in scene layout properties

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Previously we observed that pupil size is modulated by scene layout properties: smaller when viewing far or open scenes. Here we investigate whether changing direction of these properties, in addition to their static value, will also affect pupil size, by comparing pupillary response to otherwise identical scenes after exposure to scenes of different depths. 10 naive volunteers were instructed to free-view a series of 479 color video clips (mean duration ~8.57 s) in random order, while binocular pupil size was recorded using Eyelink 1000 eyetracker. All clips were extracted from documentary movies depicting natural or man-made sceneries, and were preprocessed to have roughly matched mean luminance and RMS contrast in each frame. Dominant depth of the scene in the clips was continuously rated by another group of 10 observers in separate sessions. Trials were sorted according to whether depth rating of preceding clip (adaptor) was farther, similar (served as baseline), or nearer compared with current clip (probe). Event-related pupil response time-locked to video onset was constructed for clips with at least one trial in all three conditions, and averaged across clips. When adaptor was farther, pupil size was significantly larger than baseline condition starting from as early as 280 ms, as if the probe was perceived nearer. The opposite was true when adapted to nearer scenes. Notably, larger difference in depth between adaptor and probe was significantly correlated with greater change in pupil size. Near reflex couldn't explain the result because it would predict opposite trend. In conclusion, the result suggests that pupil response is not only modulated by static value of scene layout properties, but also sensitive to their dynamic changes, probably due to high-level aftereffect in scene perception.

Acknowledgement: MSTC grant (2012CB825500), NSFC grant (91132302, 81123002), CAS grant (XDB02050001)

33.4112 Analysis of dynamic multispectral video using systems factorial technology (SFT)

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In previous research we have explored the mechanisms behind how individuals combine several different multispectral, real-world images using SFT. We compared two displays: one presented each single image beside one another and a second displayed a single algorithmically combined image. Using SFT provided us with evidence for the cognitive underpinnings that may have led to a particular pattern of performance. With this research, we found participants processing of each sensor image declined when provided multiple images, regardless of how we attempted to combine (or not combine) the imagery. Additionally, individuals exhibited the ability to process all the image information simultaneously and sometimes with full-integration. In the current work we explored whether the results of processing strategies for static imagery generalized to dynamic environments. Dynamic environments contain movement information that is highly correlated across time. Particular aspects of each single-sensor may provide redundant or complementary movement information for an operator to make a quick, accurate decision. How multiple sensors are displayed may influence redundancy gains or facilitate performance when spatially confining the information to a single visual reference space. Using short, dynamic video segments we found speed and accuracy improvements for multiple sensors presented beside one another above single sensors presented alone or algorithmically combined. Our findings agree with the previous static image results: processing efficiency of each image declines when multiple images are provided indicating people can use information from multiple images of a static scene, although with limited capacity. When short video segments are used instead of a static scene, accuracy and response times improve with redundant videos whether the two video types are displayed next to one another or are combined into a single stream. However, the gains are not sufficiently large enough to reach accuracy and response time levels predicted by unlimited capacity parallel processing.

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33.4113 Topoagnosia in panoramic pictorial space

Andrea van Doorn[1,2](J.j.koenderink@phys.uu.nl), Jan Koenderink[1,2]; [1]Abteilung Allgemeine Psychologie, Justus-Liebig Universität, Giessen, Germany, [2]Laboratory of Experimental Psychology, University of Leuven (KU Leuven), Belgium

The "planispheric optic array"' is a full-horizon Mercator projection of the optic array. Such pictures of the environment are coming in common use with the availability of cheap full-view cameras of reasonable quality. This introduces the question of whether the public will actually profit from such pictorial information in terms of an understanding of the spatial layout of the depicted scene. Test images include four persons located at the corners of a square centered at the camera. The persons point at each other in various combinations. Participants in the experiment judge who is pointing at whom in a number of such photographs. It is found that certain very systematic and huge errors are the rule, indicating that naive viewers are quite unable to parse such planispheric representations.

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SUNDAY AFTERNOON TALKS

OBJECT RECOGNITION: MECHANISMS AND MODELS

Sunday, May 21, 2:30 - 4:15 pm
Talk Session, Talk Room 1
Moderator: Antony Morland

34.11, *2:30 pm* **Classification Images Reveal that Deep Learning Networks Fail to Perceive Illusory Contours** Philip Kellman[1](Kellman@cognet.ucla.edu), Nicholas Baker[1], Gennady Erlikhman[2], Hongjing Lu[1]; [1]Department of Psychology, University of California, Los Angeles, [2]Department of Psychology, University of Nevada, Reno

Background: Deep learning networks show impressive object recognition performance and learned filters within them show correlates with neural activity in human visual areas. However, deep learning networks can also be easily fooled by adversarial examples which do not affect human recognition. We used the classification image method developed in psychophysics to probe whether a deep learning model employs the same features as humans in perceiving real and illusory contours. Method: We adapted a standard deep learning network, Convolutional Neural Networks (CNNs), pre-trained on the ImageNet dataset with 1.2 million natural images. The network was trained to perform shape discrimination in the "fat/thin" task (Ringach & Shapley, 1996) by replacing the last decision layer with a perceptron. The perceptron used the set of 4096 activations of the CNN's penultimate layer's units as input and was trained to do a novel classification between 'fat' and 'thin' shapes with 12,000 examples of these stimuli. After training, we tested with real and illusory contour stimuli contaminated with Gaussian luminance noise. The network's decisions on shape discrimination were used to combine noise fields to compute classification images. Results: Networks coupled with the new decision layer discriminated between fat and thin shapes with high accuracy (98.56%). For real contours, classification images showed behavioral receptive fields consistent with human classification images. However, in displays with gaps, where humans perceive illusory contours, the classification images from the CNN failed to reveal behavioral receptive field activity along illusory contours. Conclusions: Deep learning networks trained on natural images can be readily altered by introducing a new decision layer to discriminate between psychophysical stimuli with an extremely high degree of accuracy. However, deep learning networks do not appear to perceive illusory contours from corner inducing elements, a process readily and automatically performed in the human visual system (Gold et al, 2000).

Acknowledgement: Supported by NSF BCS-1353391 to HL

34.12, *2:45 pm* **Unconscious perception of visual stimuli reveals an early neural signature of memorability** Yalda Mohsenzadeh[1](yalda@mit.edu), Aude Oliva[2], Dimitrios Pantazis[1]; [1]McGovern Institute for Brain Research, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA, [2]Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA

Recent behavioral evidence has shown that certain images are consistently remembered and others forgotten irrespective of subjective experiences. Even though this intrinsic property of visual stimuli, termed memorability, is highly replicable across individuals, the neural circuitry subserving this behavior is currently unknown. To determine a lower boundary in the visual hierarchy for memorability-related neural signals, we investigated whether memorability information is represented at early stages of the visual system even for unconsciously perceived stimuli. We collected MEG data in a rapid serial visual presentation (RSVP) experiment. Participants (N=12) viewed streams of 11 images at 34ms/pic, a rate extremely effective in masking stimuli. The middle image (target) was randomly sampled from a set of 30 faces or 30 objects (15 memorable and 15 forgettable each), all controlled for low level features. The distractor images comprised 150 scene images with mid-level memorability scores. Participants performed a two-alternative forced choice task reporting whether a face image was present in each stream. Following the MEG experiment, a subsequent memory test evaluated memory encoding. MEG data were analyzed with time-resolved multivariate pattern analysis to decode the attribute of memorability. Behavioral results revealed that while the attended face targets were remembered, with a significant advantage to the memorable images ($p = 0.002$), the unattended object targets were at chance level, suggesting unconscious perception with no memory encoding. MEG decoding results for these object images revealed memorability information with significance onset at 131ms (95% CI: 69-232ms) and peak at 156ms (86-261ms). Taken together, our results indicate the RSVP paradigm was effective in suppressing conscious perception of object stimuli and revealed memorability-related neural signals as early as 131ms, offering corroborating evidence that the fate of a stimulus is decided early in the visual stream.

Acknowledgement: This work was funded by NSF award 1532591 and the McGovern Institute Neurotechnology Program (to A.O and D.P) and was conducted at the Athinoula A. Martinos Imaging Center, MIBR, MIT.

34.13, *3:00 pm* **Should you trust your RSA result? A Bayesian method for reducing bias in neural representational similarity analysis.** Ming Bo Cai[1](mcai@princeton.edu), Nicolas Schuck[1], Michael Anderson[2], Jonathan Pillow[1], Yael Niv[1]; [1]Princeton Neuroscience Institute, Princeton University, [2]Parallel Computing Lab, Intel Corporation

Representational similarity analysis (RSA) has become a popular tool in fMRI studies. It has recently been realized that calculating similarity between two neural patterns that were estimated during the same scanning session can induce bias in the estimated similarity matrix. However, the severity of this bias has not been fully appreciated. We analytically derive the source of the bias: serial correlations in fMRI noise, together with temporal relationships between task events, introduce structured noise in the estimated neural patterns. Correlation analysis of the estimated patterns translates the structured noise into spurious bias structure in the similarity matrix. The bias is especially severe with low signal-to-noise ratio and if experimental conditions cannot be fully randomized in the task design. For example, in an experiment in which task conditions had a fixed Markovian transition structure, 84±12% of the variance of the similarity matrix estimated from the OFC could be accounted for by this bias. We propose an alternative Bayesian framework for computing representational similarity, an extension of Diedrichsen et al., 2011. We treat the covariance structure of neural activity patterns as a hyper-parameter in a generative model of the neural data, and directly estimate this covariance structure from imaging data while marginalizing over the unknown activity patterns and parameters of autocorrelated noise. Converting the estimated covariance structure into a correlation matrix offers a much less biased estimate of neural representational similarity. Our method also simultaneously estimates a signal-to-noise map that informs where the learned representational structure is supported more strongly. In addition, the learned covariance matrix together with the SNR map can be used as a structured prior for the posterior estimation of neural activity patterns. The method also allows for learning a shared representational similarity structure across participants. Code is freely available in Brain Imaging Analysis Kit (BrainIAK, https://github.com/IntelPNI/brainiak).

Acknowledgement: Intel Corporation, the John Templeton Foundation

34.14, *3:15 pm* **Positional regularity disrupts independent coding of multiple objects in visual cortex** Marius Peelen[1](marius.peelen@unitn.it), Daniel Kaiser[1]; [1]Center for Mind/Brain Sciences, University of Trento, Italy

The human visual system has adapted to efficiently process cluttered scenes containing dozens of objects. The regular arrangement of these objects critically contributes to the efficiency of naturalistic vision. Recent studies investigating multiple object perception have demonstrated that visual cortex responses to multi-object displays can be accurately modeled by a linear combination of responses to individual objects, revealing independent processing of simultaneously presented objects. Here we use fMRI to show that this independence breaks down when objects are positioned according to frequently experienced configurations. Participants viewed pairs of objects that formed minimalistic two-object scenes (e.g., a "living room" consisting of a sofa and television) presented in their regularly experienced spatial arrangement or in an irregular arrangement (with the object

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positions interchanged). Additionally, every single object was presented centrally and in isolation. Multi-voxel activity patterns evoked by the object pairs were modeled as the average of the response patterns evoked by the two single objects forming the pair. Strikingly, in object-selective cortex (OSC), but not in early visual cortex, this approximation was significantly less accurate for the regularly than the irregularly positioned pairs. This result was replicated in a second experiment that additionally ruled out that these effects were mediated by scene imagery. These findings indicate that during naturalistic vision – when objects appear in regular arrangements – OSC does not represent the scene's objects independently. Rather, regularly co-occurring objects may be partially integrated in OSC. This may serve to reduce the descriptive complexity of the scene.

34.15, *3:30 pm* **Modeling the perceptual experience of retinal prosthesis patients** Michael Beyeler[1,2,3](mbeyeler@uw.edu), Ariel Rokem[2], Geoffrey Boynton[3], Ione Fine[3]; [1]Institute for Neuroengineering, University of Washington, [2]eScience Institute, University of Washington, [3]Department of Psychology, University of Washington

Introduction: The field of electronic retinal prostheses is moving quickly, with three varieties of retinal prostheses approved for commercial use in patients and several others in development. However, data from implanted patients make it clear that current technologies do not restore natural vision: Interactions between the electronics and the underlying neurophysiology result in significant spatiotemporal distortions of the perceptual experience (Fine and Boynton 2015) . Here we describe a linear-nonlinear cascade model, developed using a variety of patient data describing the brightness and shape of phosphenes elicited by stimulating a single electrode, that has the goal of predicting the perceptual experience of epiretinal prosthesis patients. Our goal was to see whether this model could predict data from an independent set of behavioral measures examining spatiotemporal interactions across multiple electrodes. Methods and Results: Behavioral data were collected from two Argus I epiretinal prosthesis (Second Sight Medical Products Inc.) patients, on 15 different electrode pairs with 800, 1600, or 2400 micron center-to-center separation. Subjects compared the perceived brightness of a standard stimulus (synchronous pulse trains presented across both electrodes) to the perceived brightness of a test stimulus (pulse trains across the electrode pair phase-shifted by 0.075, 0.375, 1.8, or 9 ms). A staircase procedure was used to determine the current amplitude necessary for each phase-shifted test stimulus to match the brightness of the standard. The model closely reproduced the patient psychophysical data: Specifically, the model captured spatiotemporal interactions that vary between suppression, independence, and summation depending on whether current fields overlapped and/or fell on the same ganglion axon pathway. Conclusions: Simulations such as these provide an insight into the perceptual experience of retinal prosthesis patients, can guide current and future technology development, and provide regulatory bodies with guidance into what sort of visual tests are appropriate for evaluating prosthetic performance. (http://github.com/uwescience/pulse2percept)

Acknowledgement: NEI-EY014645, Washington Research Foundation, Moore/Sloan Data Science Environments

34.16, *3:45 pm* **Combining human MEG and fMRI data reveals the spatio-temporal dynamics of animacy and real-world object size** Seyed-Mahdi Khaligh-Razavi[1](s.mahdirazavi@gmail.com), Radoslaw Cichy[2], Dimitrios Pantazis[3], Aude Oliva[1]; [1]Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA, [2]Department of Education and Psychology, Free University Berlin, Berlin, Germany, [3]McGovern Institute for Brain Research, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA

Understanding the computational principles used by the human brain to perform recognition tasks requires a comprehensive view of brain regions involved in processing the sensory information and their temporal dynamics. Here, by combining high spatial resolution (fMRI) and high temporal resolution (MEG) brain data (N=15) with theoretical models using representational similarity analysis (RSA), we reveal the spatio-temporal dynamics of processing object properties, such as animacy and real-world size, in the human brain. We show that the two properties engage overlapping but different network of brain areas. The peak for representing animacy information is earlier (~173 ms) than the peak for representing real-world object size (~196 ms) [two-sided sign-rank test, $p < 0.0001$]. Regions associated with the peak of animacy representation are bilateral PHC, VO, LO, left fusiform and MT, while regions associated with the peak size representation are right VO, left MT, and bilateral PHC. Our analyses also suggest that the animacy information is spatiotemporally more sustained than the real-world size information. The novel Content Dependent Fusion (CDF) approach proposed here for combining MEG and fMRI data further enabled us to visualize the representational connectivity finger prints of the human brain regions involved in identifying animacy and real-world size information during the first few hundred milliseconds of vision. Mapping the dynamics of neural information processing in space and time can reveal the nature of specific informational pathways allowing for a broad view of where and when the neural information is computed and transmitted for creating mental representations in the human brain.

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34.17, *4:00 pm* **Mid-level features are sufficient to drive the animacy and object size organization of the ventral stream** Bria Long[1](brialong@fas.harvard.edu), Talia Konkle[1]; [1]Department of Psychology, Harvard University

The ventral visual stream exhibits a large-scale organization by the dimensions of animacy and real-world size (Konkle & Caramazza, 2013). While this organization could reflect a conceptual-level distinction, there are also perceptual differences between animals, big objects, and small objects, evidenced by systematic mid-level feature differences (Long et al., 2016). Here, we examined whether these mid-level feature differences are sufficient to drive the ventral stream organization by animacy and object size. Using a customized texture synthesis model, we created a stimulus set from images of big animals, big objects, small animals, and small objects. These stimuli preserve mid-level information about texture and form ("texforms"), but are unrecognizable at the basic-level. Eight observers underwent functional neuroimaging while viewing texform images and the original counterparts. For each voxel in the ventral stream, we computed animacy preferences (animals – objects) and real-world size preferences (small objects – big objects), for both original and texforms images. These preference maps were correlated with each other to assess the similarity of the animacy and real-world size topographies. Overall, we found that texforms elicited robust animacy and size preference maps across the entire ventral stream. Further, these maps exhibited a highly similar spatial topography to the maps generated when observers viewed recognizable images (Animacy: $r=.76$, $t(7)=22.3$, $p< 0.001$; Size: $r=.43$, $t(7)=5.7$, $p< 0.001$). In a replication experiment, we presented images above and below fixation, and again found that texforms and original images generated similar topographies (Animacy: $r=.69$, $t(7)=9.8$, $p< 0.001$; Size: $r=.36$, $t(7)=5.4$, $p=0.001$). These results demonstrate that the ventral stream organization does not rely on intact basic-level recognition, and that mid-level feature differences drive ventral visual cortex in a way that is not simply inherited from retinotopy. Broadly, these data imply that mid-level perceptual information is represented along the ventral stream well beyond early visual areas.

Acknowledgement: Harvard University Star Family Challenge Grant

Binocular Vision: Rivalry and bistability

Sunday, May 21, 2:30 - 4:15 pm
Talk Session, Talk Room 2
Moderator: Concetta Morrone

34.21, *2:30 pm* **Neuronal responses underlying shifts in interocular balance induced by short-term deprivation in adult macaque visual cortex** Daniel Tso[1](tsod@upstate.edu), Ronald Miller[1], Momotaz Begum[1]; [1]Neurosurgery/Neuroscience, SUNY Medical University

Psychophysical studies and functional optical imaging experiments in V1 have shown that short-term monocular deprivation (STMD, depriving one eye for 1-3 hours, either total occlusion or pattern deprivation) disrupts interocular balance. In such studies, the relative contribution of the deprived eye was surprisingly elevated for more than an hour after deprivation. We have now conducted multi-electrode recordings in macaque V1 before, during and after STMD. The single-unit recordings revealed several different types of cell responses. Of a sample of 32 neurons, 40% exhibited increased relative strength of the deprived eye input after STMD, 28% strongly so (MD index > 0.25) whereas only 6% exhibited a strong relative shift favoring the non-deprived eye (MDI < -0.25). The strongest MDI increases were observed in cells where its non-dominant eye was deprived. The relative strengthening of the deprived eye was due to either a strengthening of the response to the deprived eye, or a weakening of the non-deprived eye, or both. Our previous STMD optical imaging uncovered a marked weakening of the non-deprived eye during the deprivation period that only reversed with the ending of the deprivation of the other eye. Similarly, 66% of the recorded cell sample also exhibited a marked weakening of responses to the non-deprived eye during the deprivation period. It cannot be explained by adaptation or fatigue in the eye or cortex since the weakening reverses with the ending of deprivation of the other eye. A minority (16%) of cells demonstrated responses more consistent with the classical relative weakening of the deprived eye. Overall, the results show V1 cell response behaviors that likely constitute components of the shifts in interocular balance induced by STMD observed in the imaging studies and psychophysically. The findings suggest a dynamic binocular mechanism for regulating interocular balance that involves the neurons in V1.

34.22, *2:45 pm* **Short-term monocular deprivation enhances 7T BOLD responses and reduces neural selectivity in V1**

Paola Binda[1,2](paola1binda@gmail.com), Jan Kurzawski[3], Claudia Lunghi[1,2], Laura Biagi[3], Michela Tosetti[3,4], Maria Concetta Morrone[1,3]; [1]Department of Translational Research on New Technologies in Medicine and Surgery, University of Pisa, Pisa, Italy, [2]CNR Neuroscience Institute, Pisa, Italy, [3]IRCCS Stella Maris, Calambrone, Pisa, Italy, [4]IMAGO Center, Pisa, Italy

Recent studies have shown that short-term (2h) monocular deprivation unexpectedly increases the dominance of the deprived eye in binocular rivalry, and induces a decrease of GABA concentration in the visual cortex of adult humans. GABAergic inhibition is key to determining the selectivity of neural responses, through intra-cortical lateral inhibition. A decrease of GABA after monocular deprivation would predict an increase of BOLD responses and a reduction of neuronal selectivity. We measured BOLD (at 7T) selectivity to ocular dominance and to spatial frequency by presenting narrow band-pass visual noise monocularly before and after deprivation in 10 young human adults. Using a population Receptive Field mapping approach, we modeled the responses to 5 stimuli that had the same bandwidth of 1.5oct and preferred spatial frequencies of 0.15, 0.25, 0.5, 1.3 and 3cpd to estimate the spatial frequency tuning of early visual cortex voxels. In order to assess the effect of deprivation, we also measured eye-dominance with binocular rivalry before and after deprivation and immediately before scanning. We found that monocular deprivation boosted BOLD responses in early visual areas. In V1 the boost was stronger for the deprived eye and for higher spatial frequencies, indicating a change of neural tuning for both eye-dominance and spatial frequency. At the population level, the scatter of responses increased after deprivation and the spatial frequency selectivity became broader. Importantly, the selectivity of the V1 post-deprivation BOLD responses for the deprived eye correlated with the psychophysical index of visual plasticity: observers with a stronger boost of the deprived eye in binocular rivalry had a broader tuning for eye-dominance and spatial frequency. This enhanced integration is consistent with the reduction of GABAergic inhibition of lateral inhibition and may reflect the optimal response to the homeostatic gain change that is transiently produced by the reduced stimulation of the deprived eye.

Acknowledgement: ERC-Ecsplain, H2020-NextGenVis (MCM) FIR (PB) ERANET-NeuroDream (MCM,CL)

34.23, *3:00 pm* **Mutual inhibition circuit as underlying mechanism for bi-stable perception and non-linear responses in vision**

Naoki Kogo[1](naoki.kogo@gmail.com); [1]Brain and Cognition, University of Leuven

It has been hypothesized that mutual inhibition circuit underlies bi-stable perception. It is possible that this circuit functions to resolve ambiguity of input image by quickly shifting the balance of competing signals in response to conflicting features. Furthermore, it is possible that feedback signals influence this “biased competition” to reflect global properties of the image. I developed a system to record from two pyramidal cells in primary visual cortex in vitro by double patch clamp recording technique combined with so-called “dynamic clamp” system. In this system, two neurons can be connected by modeled synapses. When a connection between the two neurons are established by mutually inhibiting model synapses, simultaneous activation of the two neurons caused bi-stable activities: dominance of neural activities alternated between the two neurons in about 1~2 seconds interval. Next, I ran paradigms analogous to various experimental paradigms used for behavioral studies of bi-stable perception. Levelt’s 4th law states that increasing the strength of input contrast causes increase of switching frequency. Similarly, increasing the depolarizing current injected to both neurons showed increase of switching frequencies at the higher range of injected current. Flash suppression paradigm was modeled by injecting depolarizing current to one neuron for few seconds followed by simultaneous injections of the current to the two neurons. The simultaneous injection evoked bi-stability that mostly started with the dominant activity of the non-adapted neuron. Intermittent presentation of bi-stable figure is known to prolong the percept duration. When this paradigm was modeled by injecting depolarizing current intermittently, the prolongation effect was not observed. Finally, by placing a stimulus electrode to V2, feedback excitation was evoked. The stimulation often caused the switch of dominance. Hence, feedback signals can influence the outcome of the competition. With this system, the details of neural processes that undergo bi-stable activities can be investigated.

Acknowledgement: FWO post-doctoral fellowship

34.24, *3:15 pm* **An attention model of binocular rivalry**

Hsin-Hung Li[1](hsin.hung.li@nyu.edu), James Rankin[2,3], John Rinzel[3,4], Marisa Carrasco[1,2], David Heeger[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University, [3]Department of Mathematics, University of Exeter, [4]Courant Institute of Mathematical Sciences, New York University

Introduction: Binocular rivalry ceases when attention is diverted away from the stimuli (Zhang et al., 2011; Brascamp and Blake, 2012). Previous models do not explain this finding. We propose a computational model to address how the dynamics of rivalry depend on attention. Model: The sensory representation is composed of 4 monocular neurons (two eyes and two orthogonal orientations), 2 binocular-summation neurons that sum responses of the monocular neurons with the same orientation preference, and 4 binocular-opponency neurons that respond to conflicting information between eyes. Moreover, two 2nd-layer neurons, selective for orthogonal orientations, driven by the responses of the summation neurons provide feedback to the monocular neurons. Rivalry is driven by: (1) Slow adaptation in monocular and summation neurons. (2) Attention: Orientation-selective feedback from the 2nd-layer neurons, analogous to feature-based stimulus-driven attention, is active under the attended condition but silent under diverted attention. This feedback enhances the multiplicative gain of whichever orientation has stronger sensory responses, and suppresses the gain of the other. (3) Mutual inhibition: When active, opponency neurons provide subtractive suppression to the monocular population with weaker responses. Results: (1) The model exhibited rivalry for attended dichoptic gratings, but not for plaid or unattended stimuli. (2) When the two images were swapped between eyes rapidly, the dominant percept either stayed with one eye or followed one orientation for a period of time, depending on the stimuli’s temporal characteristics. (3) The dominance duration changed with stimulus strength following Levelt’s propositions. With a bifurcation analysis, we identified the parameter space in which the model’s behavior was consistent with experimental results. Conclusion: In the model, attention affects rivalry by biasing competition toward the dominant feature, thereby stabilizing the percept. This is the first model that exhibits attention-dependent dynamics and captures a wide range of rivalry phenomena.

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34.25, *3:30 pm* **A predictive-coding account of multistable perception**

Philipp Sterzer[1](philipp.sterzer@charite.de), Veith Weilnhammer[1], Guido Hesselmann[1], Katharina Schmack[1]; [1]Visual Perception Lab, Charité - Universitätsmedizin Berlin

Viewing situations in which visual input is perceptually ambiguous and consistent with two or more perceptual interpretations typically give rise to bi- or multistable perception, the spontaneous fluctuation between two or more interpretations of the same sensory input. A well-established finding from neuroimaging studies into multistable perception is that spontaneous transitions between perceptual states are associated with neural activity increases in fronto-parietal areas, but it has remained controversial whether such activations reflect cause or consequence of the perceptual transition. Here, we present an account of multistable perception in the computational framework of predictive coding, according to which predictions encoded at higher hierarchical levels are compared against the sensory data represented at lower levels. A mismatch between predictions and sensory data elicits a prediction error signal that is in turn used to update predictions at higher levels. We hypothesized in the framework of predictive coding that fronto-parietal activations may reflect a prediction error signal that is evoked by the currently suppressed percept and that is building up to a point that culminates in a perceptual transition. We used a Bayesian model to estimate the time course of prediction errors during bistable motion perception. Data simulations revealed close similarities between the model's predictions and known temporal characteristics of multistable perception. Fitting the model to behavioural data from an fMRI experiment revealed that prediction error time courses are correlated with neural activity in the inferior frontal cortex, a region that has previously been implicated in causing perceptual transitions. Taken together, we provide theoretical, behavioural and neural evidence for a predictive coding account of multistable perception that posits a crucial role for prediction errors in perceptual inference from ambiguous stimuli.

Acknowledgement: German Research Foundation (DFG)

34.26, *3:45 pm* **When motion loses in interocular competition: Onset of static stimulus briefly dominates the center, regardless of eccentricity** Egor Ananyev[1,2](egor.ananyev@gmail.com), Po-Jang (Brown) Hsieh[2]; [1]Department of Psychology, National University of Singapore, [2]Neuroscience and Behavioral Disorders Program, Duke-NUS Graduate Medical School

For more than a hundred years (e.g., Breese, 1899; Grindley & Townsend, 1965; Blake et al., 1998), it was reported that motion wins over a static object in binocular competition. Here we show a striking deviation from this principle: in the first second of the interocular competition between a static (or slow) field with a fast field, the static field dominates the center, while the fast motion persists along the borders of the stimulus. This effect cannot be explained in terms of eccentricity, as it held when the rivaling stimuli were presented peripherally. Additionally, the central portion of the static/slow field scaled with the size of the stimuli (i.e., the slow-center/fast-surround ratio remained at ~4/5th of the radius). Furthermore, this phenomenon is time-locked to the onset of the static stimulus. This transient central perceptual bias toward static stimuli reveals the importance of two factors typically overlooked in binocular rivalry and interocular suppression studies: the time course of interocular competition, and relative spatial positions of target and mask.

34.27, *4:00 pm* **Distributional analyses of individual differences in binocular rivalry dynamics** Jocelyn Sy[1](jocelyn.l.sy@vanderbilt.edu), Andrew Tomarken[1], Vaama Patel[1], Randolph Blake[1]; [1]Department of Psychology, Vanderbilt University

Binocular rivalry is the dissociation of physical stimulation and perceptual experience that occurs when conflicting monocular stimuli are imaged on corresponding areas of the eyes sparking alternations in perceptual dominance between the two eyes' views. There is increasing evidence for individual differences in rivalry dynamics with important correlates to neural inhibitory processes (e.g., GABAergic signaling) and function (e.g., autism and schizophrenia). While test-retest correlations between summary measures (e.g. means) have been used to demonstrate individual differences, this approach ignores potentially important distributional features of the data. We used a novel non-parametric approach to assess the within-subjects consistency of rivalry distributions. An intensive design was used in which 15 females viewed rivalry stimuli across 15 sessions consisting of 20 60-second blocks per session. We used kernel density estimation to generate smoothed, and minimally assumptive, distributions of percept durations for each individual for the odd and even sessions. We then computed the overlap coefficient (OC; potential range = 0 to 1) between odd and even distributions by numerical integration of the region of intersection. We found a remarkably high degree of within-subjects consistency: mean and median OCs = .95 (range = .91 to .97). Within-subject OCs were markedly higher than OCs with other subjects (mean OC=.63), thus indicating that the former reflected more than stereotype consistency. Permutation tests indicated that for 4 individuals we could not reject the null hypothesis that OCs=1. We classified with high accuracy the single-session performance of viewers from their aggregate scores across independent sessions. These results indicate (1) Marked consistency in the distributions of binocular dominance durations that are characterized by a unique subject-specific "signature"; and, (2) The utility of non-parametric density estimation and the overlap coefficient for quantification of similarity and individual differences in perception studies.

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Spatial Vision: Neural Mechanisms

Sunday, May 21, 5:15 - 7:15 pm
Talk Session, Talk Room 1
Moderator: Jonathan Winawer

35.11, *5:15 pm* **Model-based functional segmentation of the human lateral geniculate nucleus** Kevin DeSimone[1,2](desimone@nyu.edu), Keith Schneider[2,3]; [1]Department of Psychology, York University, [2]Centre for Vision Research, York University, [3]Department of Biology, York University

The lateral geniculate nucleus of the thalamus (LGN) is somewhat unique in the visual pathway in that there is a clear separation of structure and function at a spatial scale that is resolvable by contemporary functional imaging techniques. Therefore, it provides a unique opportunity for developing and testing models of neural function, visual perception, and information flow throughout the brain. For instance, one prevailing theory of dyslexia contends that a malfunction in the M system throughout the brain is responsible for the behavioral deficits observed in dyslexics (Stein, 2001; Stein and Walsh, 1997). The LGN receives input from retinal ganglion cells and projectors directly to primary visual cortex, and can be functionally subdivided into layers on the basis of the response properties of the neurons contained therein. Neurons in the magnocellular (M) and parvocellular (P) layers of the LGN have distinct and complimentary spatial and temporal tuning properties. However, functionally segmenting the LGN on the basis of these neural response properties using functional brain imaging techniques has proven difficult. Recent attempts have been made to segment the LGN into its M and P subdivisions (Denison et al., 2014; Zhang et al., 2015) using fMRI. In these experiments, researchers took advantage of the complementarity of the response properties of M and P neurons to differentially drive the BOLD activity during the presentation of various stimulus features (i.e., contrast, spatial frequency, temporal frequency, color sensitivity). Here, we present a new spatiotemporal population receptive field (pRF) model that leverages the differences in the temporal frequency tuning and neural discharge patterns among M and P neural populations. This spatiotemporal pRF model estimates provide activation maps describing the LGN both in terms of its retinotopic organization and temporal response profile, and so affords an avenue for differentiating the M and P layers of the LGN.

35.12, *5:30 pm* **An anatomically-defined template of BOLD response in V1-V3** Noah Benson[1](nben@nyu.edu), William Broderick[2], Heiko Müller[3], Jonathan Winawer[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University, [3]Center for Data Science, New York University

The posterior visual field maps, V1-V3, have been well-characterized using neuroimaging techniques and computational models. One type of model, a retinotopic template, accurately predicts the retinotopic organization from the anatomical structure [Benson et al. 2012 & 2014; 10.1016/j.cub.2012.09.014 & 10.1371/journal.pcbi.100353]. A second type of model, an image-computable model, predicts fMRI response amplitude within these maps to a wide range of visual stimuli, including textures and natural images [e.g., Kay et al. 2008, 2013; 10.1038/nature06713 & 10.1371/journal.pcbi.1003079]. The parameters of these image-computable models are typically fit to fMRI data in each voxel independently. Here, we took advantage of the fact that these parameters are distributed regularly across the cortical surface, extending Benson et al.'s retinotopic templates to infer the parameters of an image-computable model, based on Kay et al. (2013). By merging these two types of models, and extending the model to incorporate multiple spatial scales, we can predict the percent BOLD change across all voxels in V1-V3 in response to an arbitrary gray-scale image in any individual subject given only the stimulus image and a T1-weighted anatomical image. Without any fitting to functional data, this model predicts responses with high accuracy (e.g., R = 0.80, 0.72, and 0.63 in V1, V2, and V3, respectively, from a sample experiment). Our model has been designed with flexibility in mind, and both source code and universal executables are freely available. Additionally, we have developed a database and website where researchers will be able to deposit anatomical data, stimulus sets, and functional data, and will be able to run our model or their own version of it. We hope that this space will facilitate the sharing of data, the comparison and further development of models, and collaboration between laboratories.

Acknowledgement: R00 EY022116-04 Data Science seed grant from Moore-Sloan Data Science Environment

35.13, *5:45 pm* **"Depth-otopic" mapping of human visual cortex** Julie Golomb[1](golomb.9@osu.edu), Daniel Berman[1], Nonie Finlayson[1,2]; [1]Department of Psychology, The Ohio State University, [2]Department of Experimental Psychology, University College London

We live in a three-dimensional world, but most studies of human visual cortex focus on 2D visual representations. In a recent study, we revealed that visual cortex gradually transitions from 2D-dominant representations to balanced 3D (2D plus depth) representations along the visual hierarchy, with position-in-depth information decoded along with 2D spatial information in a number of intermediate to higher-level visual areas, including V3A, V3B, V7, MT, and LOC (Finlayson, Zhang, & Golomb, forthcoming). But what is the nature of these position-in-depth representations? Do these regions contain topographic maps of depth in addition to 2D retinotopic maps? To explore this question, we developed two novel "depth-otopic" mapping paradigms, modifying traditional 2D phase-encoded (ring/wedge: Engel et. al., 1994; Sereno et. al., 1995) and population receptive field modeling (pRF: Dumoulin & Wandell, 2008) techniques. Subjects viewed 3D stimuli in the scanner while wearing red/green anaglyph glasses. Full-field random dot motion stimuli were presented in sequences of gradually shifting cycles (phase-encoded experiment) and sequences (pRF experiment). We estimated each voxel's preferred position-in-depth and modeled its tuning function. Within regions sensitive to depth information, voxels were clustered together exhibiting similar position-in-depth preferences and tuning functions. Interestingly, most of the strongest-tuned voxels tended to exhibit a preference for near (front) depths. Broader tuning was found in early visual cortex, where position-in-depth was less able to be decoded. Depth preference patterns were highly reliable within individuals, but exhibited substantial variability across subjects. The results suggest that depth-selective voxels are not randomly distributed, yet do not appear to form a strict map-like organization akin to 2D retinotopic maps.

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35.14, *6:00 pm* **Radial asymmetries in population receptive field size and cortical magnification factor in early visual cortex** Ben Harvey[1,2](b.m.harvey@uu.nl), Jan Brascamp[3], Sónia Ferreira[4], Miguel Castelo-Branco[4,5], Serge Dumoulin[1], Maria Silva[4]; [1]Experimental Psychology, Helmholtz Institute, Utrecht University, [2]Faculty of Psychology and Education Sciences, University of Coimbra, [3]Department of Psychology, Michigan State University, [4]Institute for Biomedical Imaging and Life Sciences (IBILI), Faculty of Medicine, University of Coimbra, [5]Institute of Nuclear Sciences Applied to Health (ICNAS), Faculty of Medicine, University of Coimbra

Human visual cortex does not represent the whole visual field with the same detail. Changes in receptive field size, population receptive field (pRF) size and cortical magnification factor (CMF) with eccentricity are well established, and associated with changes in visual acuity with eccentricity. Visual acuity also changes across polar angle. However, it remains unclear how RF size, pRF size and CMF change across polar angle. Here, we examine differences in pRF size and CMF across polar angle in V1, V2 and V3 using pRF modeling of human fMRI data. In these visual field maps, we find smaller pRFs and larger CMFs in horizontal (left and right) than vertical (upper and lower) visual field quadrants. Differences increase with eccentricity, approximately in proportion to average pRF size and CMF. Similarly, we find larger CMFs in the lower than upper quadrant, and again differences increase with eccentricity. However, pRF size differences between lower and upper quadrants change direction with eccentricity. Finally, we find slightly smaller pRFs in the left than right quadrants of V2 and V3, though this difference is very small, and we find no differences in V1 and no differences in CMF. Moreover, differences in pRF size and CMF vary gradually with polar angle and are not limited to the meridians or visual field map discontinuities. Thus, the early human visual cortex has a radially asymmetric representation of the visual field. These asymmetries may underlie consistent reports of asymmetries in perceptual abilities.

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35.15, *6:15 pm* **Transcranial electric stimulation (tES) to early visual areas alters large-scale functional connectivity.** Shuhei Shima[1](shima@fechner.c.u-tokyo.ac.jp), Kristina Visscher[2], Joseph Griffis[3], Aaron Seitz[4], Yuko Yotsumoto[1]; [1]Department of Life Sciences, The University of Tokyo., [2]Department of Neurobiology, University of Alabama at Birmingham., [3]Department of Psychology, University of Alabama at Birmingham., [4]Department of Psychology, University of California Riverside.

Visual areas are functionally connected with higher cortical areas, and these connections with large-scale brain networks are known to shape visual perception. Recent research suggests that transcranial electric stimulation (tES) can induce changes in brain activity. To better understand how tES influences visual processing networks, we examined how tES modulated the connectivity of early visual areas both during and after stimulation. Ten participants took part in five fMRI sessions conducted on five different days, during which they received different stimulation protocols: transcranial direct current stimulation (tDCS), 10 Hz transcranial alternating current stimulation (tACS), high-frequency transcranial random noise stimulation (hf-tRNS), low-frequency transcranial random noise stimulation (lf-tRNS) and sham. The anodal electrode was placed over the scalp location Oz and the cathodal electrode was placed over Cz. In each session, participants underwent three 12 minute resting-state fMRI scans with their eyes open. tES was applied only during the second scan. Changes in functional connectivity with early visual areas during stimulation was defined as the contrast between the second and first scans, and changes in the connectivity after stimulation was defined as the contrast between the third and first scans. The results showed that (1) tDCS to the visual cortex induced an increase in functional connectivity with cerebellum and decreases in functional connectivity with right SMA and right inferior temporal gyrus during stimulation, (2) tDCS to the visual cortex induced a decrease in functional connectivity with right inferior temporal gyrus after stimulation and (3) tACS to the visual cortex induced an increase in functional connectivity with right-frontal pole after stimulation. These data suggest that tES changes the functional connections of visual processing areas, and that some of these effects are persistent after termination of the stimulation. We will further discuss implications of tES to visual cortex and its effects on the cortical networks.

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35.16, *6:30 pm* **Comparative neuroanatomy of occipital white matter tracts in human and macaque** Hiromasa Takemura[1,2](htakemur@nict.go.jp), Franco Pestilli[3], Kevin Weiner[4], Georgios Keliris[5,6], Sofia Landi[7], Julia Sliwa[7], Frank Ye[8], Michael Barnett[4], David Leopold[8], Winrich Freiwald[7], Nikos Logothetis[5], Brian Wandell[4]; [1]Center for Information and Neural Networks (CiNet), National Institute of Information and Communications Technology, and Osaka University, [2]Graduate School of Frontier Biosciences, Osaka University, [3]Department of Psychological and Brain Sciences, Indiana University, [4]Department of Psychology, Stanford University, [5]Max Planck Institute for Biological Cybernetics, [6]Bio-Imaging Lab, Department of Biomedical Sciences, University of Antwerp, [7]The Rockefeller University, [8] Neurophysiology Imaging Facility, National Institute of Mental Health, National Institute of Neurological Disorders and Stroke, National Eye Institute, National Institutes of Health

The macaque monkey has been an important model for understanding human vision. A substantial literature compares human and macaque functional cortical responses to visual stimuli in order to better understand cellular mechanisms from macaque studies (Tootell et al. 2003; Wandell and Winawer 2011; Vanduffel et al. 2014). The anatomical connections in

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the white matter are another important source for clarifying the similarities and differences between human and macaque cortex. Recent progress on diffusion MRI and tractography enables us to identify major white matter pathways from human brains (Catani et al. 2002; Schmahmann et al. 2007; Wandell 2016). This study compares the organization of major occipital white matter tracts in human and macaque. We analyzed diffusion MRI data, collected from 4 macaques and 10 humans using the Ensemble Tractography method (Takemura et al., 2016). We identified several apparently homologous tracts in the two species, including the vertical occipital fasciculus (VOF), optic radiation, forceps major, and inferior longitudinal fasciculus (ILF). There is one large human tract, the inferior fronto-occipital fasciculus, with no corresponding fasciculus in macaque. Then we focused on the macaque VOF, which has been little studied (Yeatman et al., 2014). The estimated macaque VOF position is consistent with classical invasive anatomical studies by Wernicke. The homology of human and macaque VOF is supported because the endpoints are near similar maps (V3A and ventral V4) between human and macaque. However, the macaque VOF fibers intertwine with the dorsal segment of the ILF, while the human VOF are relatively lateral to the ILF. These similarities and differences will be useful in establishing which circuitry in the macaque can serve as an accurate model for human visual cortex.

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35.17, *6:45 pm* Uncertainty in cortical stimulus representations predicts serial dependence effects in orientation perception

Ruben van Bergen[1](r.vanbergen@donders.ru.nl), Janneke Jehee[1]; [1]Donders Institute for Brain, Cognition & Behavior, Radboud University, Nijmegen, The Netherlands

How does the brain make sense of variable and unreliable sensory input from an external world that is largely stable over short periods of time? A statistically optimal observer would capitalize on the world's stability by integrating past and present sensory inputs, weighting each by the uncertainty in its neural representation. Here, we use fMRI in combination with a probabilistic decoding algorithm to test this prediction. Participants viewed sequences of randomly oriented gratings, and reported their orientation. Consistent with previous behavioral work (Fischer & Whitney, 2014), we found that the stimulus orientation observers reported on the current trial was biased towards the orientation presented on the preceding trial, suggesting that their perception reflected a combination of current and previous sensory input. To test whether previously seen stimuli influenced perceptual decisions more strongly when current sensory information was less reliable, we used a probabilistic decoding algorithm to estimate sensory uncertainty from stimulus representations in early visual cortex (V1-V3 combined). Interestingly, comparing stimulus uncertainty between consecutive trials revealed that behavioral biases towards previously seen gratings were larger when the cortical stimulus representation on the present trial was more uncertain. This suggests that serial dependence effects in behavior are underpinned by a statistically optimal sensory integration process, in which uncertain sensory information is given less weight.

35.18, *7:00 pm* Frequency and phase-specific direct interaction in visual cortex between visually evoked and tACS induced neuronal signals

Zhouyuan Sun[1](sunzy0731@126.com), Linan Shi[1], Peng Zhang[1], Sheng He[1,2]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, Beijing, China, [2]Department of Psychology, University of Minnesota, Minneapolis, Minnesota, United States of America

Recently, evidence has emerged that tACS (transcranial alternating current stimulation) can modulate neural oscillations and affect visual perception. However, it remains unclear whether there is frequency and phase-specific direct interaction between visually evoked signals and tACS induced neuronal activities in the human visual cortex. Here, we investigated whether tACS can produce visible "beats" with a luminance flicker when their temporal frequencies were slightly different: a signature of frequency and phase-specific interaction between the two neural signals in the visual cortex. The visual stimulus was a uniform flickering disk with its luminance modulated at 10Hz. In a two-interval forced-choice paradigm, the 10Hz luminance flicker was presented in both intervals, each for 10 seconds separated by 4 seconds. During these two intervals, tACS stimulation was applied to the occipital pole of subjects, at 10Hz for in one interval and at 12Hz for the other. Subjects made forced-choice response to indicate which interval contained 2Hz visual beats. Results showed that subjects could consistently (accuracy 67.5%, 75%, 77.05%, 95% from 4 subjects, respectively) detect the 2Hz visual beats in the interval with the 12Hz tACS. Control experiments ruled out the possibility that subjects could detect which interval had the 12Hz tACS alone without the visual flicker. This finding suggests that there is direct frequency and phase-specific interaction between visually evoked and tACS induced neuronal signals in the visual cortex.

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Multisensory Processing

Sunday, May 21, 5:15 - 7:15 pm
Talk Session, Talk Room 2
Moderator: Li Zhaoping

35.21, *5:15 pm* New rehabilitation technology for visually impaired children and adults based on multisensory integration

Luigi Cuturi[1](luigi.cuturi@iit.it), Giulia Cappagli[1], Sara Finocchietti[1], Elena Cocchi[2], Monica Gori[1]; [1]Unit for Visually Impaired People, Istituto Italiano di Tecnologia, [2]Istituto David Chiossone Onlus

The absence of vision as in pathological blindness may induce impairments in the functioning of the remaining senses affecting psychomotor, social and emotional development. Our previous studies demonstrated that blind individuals are impaired in understanding audio-spatial relationship between sounds horizontally displayed (Gori et al 2014; Vercillo et al. 2016) and arranged in a matrix (Cappagli et al. 2015) as well as in encoding sound motion (Finocchietti et al. 2015). As pointed out in our recent reviews (Gori et al. 2016, Cuturi et al. 2016), to date most of the technological devices for visually impaired individuals is not suitable for young children and not meant for rehabilitation. For this reason, we developed a bracelet that produces a sound when a movement occurs (ABBI, Audio Bracelet for Blind Interaction; www.abbiproject.eu) whose main aim is to improve spatial, mobility and social skills in visually impaired children. It is based on the idea that the audio feedback related to body movements helps representing the surrounding space. We performed one day study in 20 early blind adults and three months longitudinal study in 20 children. In the first study, two minutes training with ABBI improved subjects' performance when asked to indicate the end-point of sound motion stimuli. In the second study, we tested 10 blind and 10 low vision children (8-17 y.o.) showing that use of ABBI over three months significantly improved performance in auditory localization and bisection as well as in motor tasks. One year follow-up analysis confirmed that children spatial improvement is related to prolonged training performed with ABBI. Our results show that a rehabilitation training based on the association between auditory and motor signals can foster the development of spatial cognition in visually impaired children enabling the intact senses to compensate for the lack of visual experience with long lasting effects.

Acknowledgement: European ABBI project (FP7-ICT-2013-10-611452)

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35.22, *5:30 pm* A generalized sense of number for perception and action Roberto Arrighi[1](roberto.arrighi@gmail.com), Giovanni Anobile[2], Irene Togoli[1], David Burr[1,3]; [1]Department of Neuroscience, Psychology, Pharmacology and Child health (NEUROFARBA), University of Florence, Italy, [2]Department of Developmental Neuroscience, Stella Maris Scientific Institute, Pisa, italy, [3]Institute of Neuroscience, National Research Council (CNR), Pisa, Italy

Much evidence suggests that humans and many animals possess an abstract sense of approximate quantity: a sense of number. Recently Arrighi et al. (2014) provided behavioral evidence for a generalized number sense by showing that numerosity adaptation occurs cross-modally (from vision to audition and viceversa) and across stimuli presentation format (sequential and simultaneous). Here we extend these findings to show that producing a sequence of motor actions (finger tapping) without tactile feedback (no finger/surface contact during the motor routine) also causes adaptation of numerosity estimation of visual stimuli. In the "high adaptation" condition, participants were asked to tap as quickly as possible (average 5-6 taps/s) whilst in a "low adaptation" condition they were required to tap more slowly (around 1 tap/s). After the adapting phase the test stimulus – either a sequence of flashes or a cloud of dots (tested on separate sessions) – was randomly displayed either to the same side of the screen where the hand had been tapping or to the symmetrically opposite side and participants had to estimate the numerosity of the test stimulus, which varied randomly from trial to trial within the range 6-14. A short period of rapid finger-tapping (without sensory feedback) caused subjects to underestimate the number of visual stimuli presented near the tapping region, and slow tapping caused overestimation. Adaptation to self-produced actions distorted perceived numerosity by about 20%, both for stimuli presented sequentially (series of flashes) and simultaneously (clouds of dots). Importantly, adaptation was spatially selective in external not body coordinates. Taken together these results support previous studies reporting links between perception and action, showing that vision and action share mechanisms that encode number: a generalized number sense, which estimates the number of self-generated as well as external events.

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35.23, *5:45 pm* Top-down working memory reorganization of the primary visual cortex: Granger Causality analysis Lora Likova[1](lora@ski.org), Laura Cacciamani[1,2], Spero Nicholas[1], Kris Mineff[1]; [1]Smith-Kettlewell Eye Research Institute, [2]California Polytechnic State University

Background. Our previous studies have implicated the primary visual cortex (V1) as the putative visuo-spatial 'sketchpad' for working-memory, but in a supramodal form. To establish this memory-related role for V1, we need to determine the source of its top-down modulation from higher-order memory mechanisms, including medial-temporal lobe (MTL) structures such as the hippocampus and perirhinal cortex (PRC) (Likova, 2012, 2013), which has direct anatomical connection to V1 (Clavagnier et al., 2004). Indeed, V1 and the hippocampus exhibited correlated changes under a memory-based training intervention (Likova, 2015); moreover, the representations for both memory and perception were confirmed as supramodal in PRC (Cacciamani & Likova, 2016). Now, to address the key question of the direction and significance of influence between these memory areas and V1, we ran Granger Causality analysis. Methods. Using fMRI in blind subjects before and after a unique memory-guided drawing intervention (Cognitive-Kinesthetic training), previously shown to generate V1 reorganization towards tactile-memory function in the blind, we ran three tasks (20s each): tactile exploration of raised-line drawings of faces and objects, tactile memory retrieval via drawing, and a scribble motor/memory control. Results. Comparative pre/post Granger Causality analysis revealed a significant increase in hippocampus-to-V1 and PRC-to-V1 causal influence after training with the memory-drawing task, but not during the control task, indicating that the drawing-from-memory training strengthened the top-down effect on visual cortex from these MTL structures. Conclusion. This is the first study to demonstrate causal connectivity from the hippocampus and PRC to V1. That this happens as a result of a memory-training intervention supports our hypothesis of the role of these memory structures as a top-down source for the cortical reorganization of V1 in the blind, and is consistent with its proposed function as a supramodal working-memory 'sketchpad' for the active processing of detailed spatial information (Likova, 2012).

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35.24, *6:00 pm* Touch dominates vision in a shape processing task – a virtual-reality study. Hyeokmook Kang[1](khm_812@naver.com), Christian Wallraven[1]; [1]Cognitive Systems Lab, Korea University

Although humans are experts for visual shape processing, several recent studies have demonstrated that haptics can also create highly detailed shape representations. Here, we investigate how vision and touch are processed when both are put in a potentially noticeable conflict in a shape similarity judgment task. To have full control over the parameters of the conflict, we use a novel, calibrated virtual reality setup in which observers see their hand exploring an object, while touching a physical instantiation at the same time in the real world. For the experiment, N=18 participants explored two objects in succession (one baseline and one test object) in each trial and indicated whether they were the same or different. Stimuli were taken from a parametrized morph-space of novel, three-dimensional objects varying in perceptually equidistant steps. We used two randomly interleaved staircases to identify the morph-parameter difference for which an object would be perceived as "same", compared to one of two baseline objects. Importantly, the staircases were run in two conditions: a congruent condition, in which the visually- and haptically-explored objects were the same and an incongruent condition, in which the haptic information for the test object was much closer to the baseline object than the visual information. Paired t-tests on the final morph-parameter differences in the congruent and incongruent condition showed that participants perceived the incongruent conditions to be much closer to the baseline condition than the congruent conditions ($t(17)=14.36$, $p< .001$), indicating that the haptic input influenced the overall judgment. Surprisingly, 15 out of 18 participants even showed "haptic capture" in this conflict condition, choosing to largely ignore the visual information (which was judged by all participants to be highly realistic in the virtual-reality display). Our results show that even for shape processing, haptic information can override visual input in a supra-threshold conflict task.

Acknowledgement: National Research Foundation of Korea, Grant 2015S1A5A8018134

35.25, *6:15 pm* Tactile stimulation disambiguates the perception of visual motion paths Hauke Meyerhoff[1](h.meyerhoff@iwm-kmrc.de), Simon Merz[2], Christian Frings[2]; [1]Leibniz-Institut für Wissensmedien, Tübingen, Germany, [2]Department of Psychology, University of Trier

The visual system continuously resolves ambiguity within the retinal information with respect to the shape as well as relative size and speed of objects by applying heuristics such as the Gestalt principles. With more than one object moving in a dynamic scene, the correspondence between object locations over time also needs to be disambiguated. Here, we study this phenomenon using displays in which two discs move toward each other, superimpose in the center of the screen, and then moved apart. This display is perceptually ambiguous because it is consistent with the interpretation of two discs streaming past each other as well as the interpretation of two discs bouncing off each other. We show that the visual system incorporates coinciding tactile information in order to disambiguate the motion paths of two dynamic objects by measuring explicit impressions (i.e., asking participants whether they perceive streaming or bouncing) as well as implicit perceptual processes (i.e. the perceived overlap between the moving discs). In the first of two experiments, we observed that the dominant interpretation of the motion paths switched from streaming to bouncing when a brief vibrotactile stimulation (applied to the left hand of the participants) coincided with the moment of overlap between the two moving discs. In the second experiment, the participants adjusted the overlap between two additional static discs until it matched with the perceived overlap of the ongoing bouncing/streaming event. The results of this experiment showed that coinciding tactile stimulation also reduced the perceived overlap between the two moving discs thus leaving a larger uncovered illusory crescent. In return, this larger crescent might induce the impression of bouncing rather than streaming. Our results therefore suggest that the tactile information indeed altered the visual percept of the dynamic event rather than the subsequent cognitive interpretation of an otherwise unaffected visual percept.

35.26, *6:30 pm* Duration of vection generated by rotating dot patterns in peripheral correlates with VEP suppression in central visual field

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Exposed to large coherently moving scene can generate illusion of self-motion perception (vection) among stationary viewers. Depending on the susceptibility to visually induced motion sickness (VIMS), the vection experiences can vary. Past studies exploring the brain activity during vection did not focus on vection onset and individual differences in vection perception. This study aims to identify EEG markers that correlate with the onset and duration of individual vection perception, along with the VIMS susceptibility. We recorded pattern-reversed visual evoked potentials (VEPs) in central visual field while two types of stimuli (static vs. rotating dot pattern) were presented to the peripheral visual field. Eight subjects were recruited with sufficient training to fix their eyes in the central fixation point and press buttons to report their perception state (vection or no-vection) during the stimuli presentation. An achromatic checkerboard reversing every 500ms was used to evoke VEPs. A total of 400/1000 flipping trials was recorded for static/rotating condition respectively. EEG signal from occipital electrodes and Fz/Cz were collected together with EOG. Trials polluted by eye movement, eye-blinks and button pressing were rejected. Significant reductions in peak amplitudes of N1/P1 components were found in trials reported with vection, compared with trials without vection (see supplemental material). Moreover, we found the suppression effects in N1/P1 were correlated with the individual vection duration. The longer the vection, the stronger the suppression in N1/P1 amplitudes was found. Additionally, the strength of effect in P1 significantly predicted VIMS susceptibility of subjects as measured by MSSQ-short. Findings suggested that N1/P1 can be potential objective indicators for vection, while P1 could also be utilized for VIMS prediction with further validation and exploration.

Acknowledgement: The work is partially supported by the HK Grants Council through grants 16200915 and 618812.

35.27, *6:45 pm* Preferred screen orientation depends on body tilt: a virtual reality study

Nicolas Davidenko[1](ndaviden@ucsc.edu), Alisia Martinez[1], Brent Hickey[1], Jennifer Day[1]; [1]Psychology Department, UC Santa Cruz

Visual tasks that are sensitive to in-plane orientation (e.g. perception of biological motion; face recognition) depend not only on the orientation of stimuli with respect to the egocentric reference frame, but also with respect to external reference frames such as gravity and the visual environment. Here we use immersive virtual environments (VEs) to investigate how egocentric and external reference frames interact in a screen orientation preference task. Participants (206 UC Santa Cruz undergraduates) observed an 8-minute video of a soccer match while sitting upright or tilting sideways at 30°, 60°, or 90° and wearing an Oculus Rift CV1 head-mounted display. This paradigm allowed us to dissociate vestibular and visual orientation cues. Participants in the "fixed room" condition (n=54) were immersed in a stable VE that was always aligned with gravity; in the "changing room" condition (n=64) the VE changed across blocks and was aligned with participants' own body orientation; in the "dark room" condition (n=64), the VE was dark and only the display screen was visible. At each of the four body positions, the display screen randomly changed its orientation every 20 seconds, and participants were instructed to readjust its orientation until they felt it most comfortable for viewing. Average screen orientation preferences depended systematically on both body tilt and the orientation of the VE. In both the "dark room" and "fixed room" conditions, as participants tilted (counterclockwise) at 30°, 60°, and 90°, their preferred screen orientations were (clockwise) 10°, 13°, and 12°, respectively (relative to their egocentric frame). In contrast, in the "changing room" condition when the VE was aligned with participants' body, preferred screen orientations were close to 0°: (clockwise) 2°, 4°, and 5°, respectively. Our results indicate a significant interaction between body tilt and visual orientation cues in predicting screen orientation preferences.

Acknowledgement: Hellman Fellowship awarded to ND

35.28, *7:00 pm* Efficient coding as the provenance of matched and opposite neuronal feature preferences for multisensory and multimodal inputs

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When inputs from different sources are correlated, coding them efficiently (Barlow 1961) requires new representations (also called bases) in which the signals are decorrelated. For two sources, this implies two bases involving the respective weighted sum and difference of the inputs. Efficient coding explains many neural receptive field properties in early vision. For example, in stereo coding (Li & Atick 1994), some V1 neurons prefer the sum of inputs from the two eyes and other V1 neurons prefer the difference of these inputs. Input correlation also appears deeper in the brain when multisensory inputs or different unisensory cues converge. For example, medial superior temporal (MST) cortical neurons sense heading direction of self-motion based on optic flow and vestibular inputs; middle temporal (MT) cortical neurons sense depth from binocular disparity and motion parallax. Analogous to stereo, efficient coding predicts that the preferred features (heading direction or depth) from different sources should be matched in some neurons and opposite in others, as indeed is found in MST (Gu, Angelaki, DeAngelis 2008) and MT (Nadler et al 2013). Efficient coding thus accounts for the existence of opposite neurons, which appear useless for cue integration, and instead convey information missed by the matched neurons when input sources are only partially redundant. It predicts how the exact forms (i.e., relative weighting of the sources) of, and neural sensitivities to, individual bases, manifested by the matched and opposite neurons, should adapt to the statistical properties of the inputs (e.g., the correlation between the sources and signal to noise ratios). Generalization to more than two sensory modalities, e.g., vision, audition, and touch, and/or multiple unisensory cues is straightforward. For example, coding of triple-source inputs should be analogous to efficient coding of inputs from red, green, and blue cones (Atick, Li, Redlich 1992) to give three decorrelated bases.

Acknowledgement: The Gatsby Charitable Foundation

SUNDAY AFTERNOON POSTERS

MOTION: NEURAL MECHANISMS

Sunday, May 21, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

36.3001 **Photopic motion sensitivity at high temporal frequencies is limited by the dark light of the eye, not quantal noise**

Remy Allard[1](remy.allard@inserm.fr), Angelo Arleo[1]; [1]Sorbonne Universités, UPMC Univ Paris 06, INSERM, CNRS, Institut de la Vision, 17 rue Moreau, 75012 Paris, France

Absolute detection threshold in total darkness is limited by internal noise independent of background intensity caused by spontaneous activity of photoreceptors or retinal cells. This 'dark light of the eye' causes incremental threshold to be independent of very low background intensities (linear law). Under photopic conditions, incremental threshold to low spatiotemporal frequencies is proportional to background intensity (i.e., Weber law; contrast sensitivity independent of background intensity) and is therefore undoubtedly limited by neural noise arising after contrast normalization. For high spatial frequencies, incremental threshold is proportional to the square root of the background intensity (de Vries-Rose law), which is explained by quantal noise resulting from the probabilistic absorption of photons by photoreceptors. For high temporal frequencies, however, incremental threshold is independent of background intensity (i.e., linear law; contrast sensitivity proportional to background intensity) even under photopic conditions, but has been nevertheless attributed to quantal noise, presumably because dark light is expected to have a negligible impact at high background intensities. In the current study, we investigated the properties of the noise limiting photopic motion sensitivity by measuring contrast threshold for a direction discrimination task in absence of noise and in high noise as a function of temporal frequency and background intensity. This method enabled us to derive equivalent input noise, which was found to have a U-shape as a function of temporal frequency. Given that quantal noise is temporally white and is not preceded by any temporal filtering, these results are incompatible with the quantal noise hypothesis. On the other hand, the linear law observed at high temporal frequencies suggests that the limiting noise was independent of background intensity and occurred before contrast normalization. Such an intensity-independent noise needs to result from early spontaneous activity independent of background intensity, namely, the dark light of the eye

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36.3002 **Elucidating the functional specialization of motion sensitive cortical regions in congenitally blind and sighted adults.**

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The human motion-sensitive middle temporal cortex, known as the hMT+ complex, is responsible for processing different types of visual motion cues in sighted individuals. It has been suggested that hMT+ may be a supramodal area, with evidence from fMRI studies showing BOLD responses to both tactile and auditory motion within this region (Hagen et al., 2002; Poirier et al., 2005). Furthermore, research has shown that hMT+ responds to auditory and tactile motion in early blind individuals (Jiang, Stecker, & Fine, 2014; Matteau, Kupers, Ricciardi, Pietrini, & Ptito, 2010). This study aims to elucidate the functional specialization of hMT+ in response to auditory and tactile motion in early blind and sighted individuals. Specifically, the supramodal nature of hMT+ is assessed using fMRI. Tactile and auditory motion tasks are administered to early blind and sighted adults to ascertain whether 1) auditory and tactile motion cues result in BOLD responses in hMT+, 2) BOLD responses to tactile and auditory motion cues overlap within hMT+, or 3) whether these motion cues are processed in functionally distinct cortical regions in both groups, as has previously been found for tactile and visual motion in sighted individuals (Jiang, Beauchamp, & Fine, 2015). This study comprises four early blind and four sighted controls presented with tactile motion (brush stimulating the volar forearm) and auditory motion (looming and receding sounds). An additional visual motion task (looming and receding ball) and visual field localizers are employed to map hMT+ within the sighted group. Individual subject analyses reveal the functional specialization of hMT+ in both early blind and sighted controls. The results of the current study go towards understanding the role of hMT+ in processing motion cues in early blind adults and have far-reaching implications for the design of sensory substitution devices for this cohort.

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36.3003 **fMRI reveals S-cone and achromatic contributions to motion-in-depth perception**

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Motion in depth (MID) can be perceived due to a change in disparity over time (CD) or inter-ocular velocity differences (IOVD). Both cues to MID appear to be processed in extrastriate motion areas but their precise neural substrates are unclear. We used fMRI to investigate how signals carried by the luminance and S-cone pathways contribute to CD and IOVD processing. S-cone isolating and achromatic stimuli driving CD or IOVD mechanisms, as well as monocular-motion-matched controls, were presented in an interleaved, rapid event-related fMRI design. Participants (N=10) performed an attentionally demanding task at fixation throughout all scans. The subjective S-cone isoluminance point was determined in situ prior to scanning using a minimum flicker task. Retinotopic mapping was performed on all subjects to delineate early visual areas (V1, V2 and V3). Areas V3A/B, hMT and hMST were identified in additional localiser scans based on their receptive field sizes and motion selectivity. We used a general linear model to identify the responses within regions of interest (ROI) to each stimulus type. Beta weights for each condition within each ROI were averaged across participants, revealing response profiles at a group level across visual cortex. Responses in early visual areas showed no preference for MID overall, and responses to achromatic stimuli were comparable to those for S-cone stimuli. In comparison, areas hMT and hMST showed selectivity to both types of achromatic MID stimuli. Surprisingly, we also found a selective response to S-cone IOVD in areas V3A/B, hMT and hMST, while the response to S-cone CD and controls in these areas was negligible. These findings provide novel evidence for the role of S-cone signals in MID processing. Specifically, they suggest that dichoptic S-cone motion signals may be combined in an opponent manner in these areas to provide input to an IOVD-based motion-in-depth system.

Acknowledgement: Biotechnology and Biological Sciences Research Council (BBSRC)

36.3004 **Neural Basis of the Double-Drift Illusion**

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When a Gabor patch moves along a path on an equiluminant background in one direction while its internal texture drifts orthogonally to the path, it can appear to deviate from its physical path by 45˚ or more (infinite regress illusion, Tse & Hsieh, 2006; curveball illusion, Shapiro et al., 2010, Kwon et al., 2015; double-drift illusion, Lisi & Cavanagh, 2015). Despite this remarkable perceptual effect, saccades to the Gabor are immune to the illusion (Lisi & Cavanagh, 2015). The present study investigated where and how this illusion is coded in retinotopic visual areas. We used fMRI and multivariate pattern analysis to classify the activation patterns driven by two illusory motion paths of the double-drift stimulus that shared the same physical path but had opposite directions of internal motion. We contrasted

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that to two physically different motion paths without internal motion that matched the perceived illusory orientations of the first two stimuli. Results showed that the classification accuracy was quite high (70 to 80%) for the two physically different motion paths in V1-V3 and area MT+, confirming that physical paths differing by 80° to 100° in orientation are decodable in these areas. In contrast, for the two illusory motion paths, decoding performance was poor in areas V1 and MT+ but was significantly above chance in V2 and V3 (about 60%), suggesting that the perceptual divergence of the double-drift stimulus emerged at V2 and V3. Given the distinct anatomical gaps across the meridians in retinotopic visual areas, our results are consistent with the previous behavioral findings that the magnitude of the double-drift illusion is degraded at both the vertical and horizontal meridians (Adamian & Cavanagh, 2015; Liu & Cavanagh, 2016), suggesting the involvement of quadrant-based visual areas V2 and V3 but not the hemifield-representing V1.

36.3005 Duration thresholds for motion discrimination of complex stimuli show non-linear interactions between motion sensors

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Previous research has shown that motion direction discrimination for complex stimuli composed of fine and coarse scales is impaired when both components move together at the same speed (Serrano-Pedraza, Goddard & Derrington, JoV, 2007). This increment of duration thresholds for motion discrimination was higher if the contrast of the coarse-scale component was lower than the contrast of the fine-scale component (Luna & Serrano-Pedraza, 2016, VSS). Here we performed two experiments where we used Bayesian staircases to measure duration thresholds for motion discrimination. In the first experiment we tested whether the relative phase of coarse- and fine-scale components (vertical-Gabor patches) had an effect on duration thresholds that could explain the impairment in motion discrimination. In the second experiment we tested complex stimuli composed of two Gabor patches of different spatial frequencies and same contrast (28%). Two types of stimuli were used: simple horizontally drifting vertical-Gabor patches and complex vertical-Gabor patches resulting from the addition of two Gabor patches of different spatial frequencies. We tested spatial frequencies ranging from 0.25 to 6c/deg and 20 different combinations between them. Results from the first experiment show that duration thresholds were independent of the relative phase of the components of the complex stimuli. The second experiment shows that a) duration thresholds decrease with increasing spatial frequency from 0.5 to 6c/deg; b) duration thresholds for complex stimuli were always larger than those for the higher spatial frequency component; and c) when the lowest frequency of the pair was 0.25c/deg, duration thresholds were shorter than for 0.25c/deg presented alone. Our results are in agreement with previous results that suggest a nonlinear interaction between motion sensors tuned to coarse and fine scales.

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36.3006 Area prostriata in the human brain

Kyriaki Mikellidou[1](k-mikellidou@gmail.com), Jan Kurzawski[2], Francesca Frijia[3], Domenico Montanaro[3], Vincenzo Greco[4], David Burr[5,6], Maria Concetta Morrone[1,2]; [1]Department of Translational Research on New Technologies in Medicine and Surgery, University of Pisa, Italy, [2]Stella Maris Scientific Institute, Pisa, Italy, [3]Fondazione CNR/Regione Toscana G. Monasterio, Pisa, Italy, [4]Istituto Nazionale di Ottica, CNR, Florence, Italy, [5]Department of Neuroscience, Psychology, Pharmacology and Child Health, University of Florence, Italy, [6]Neuroscience Institute, CNR, Pisa, Italy

Area prostriata has been well described in the marmoset monkey, but its homologue in the human cortex remains unclear. Here we use functional magnetic resonance together with a novel wide-field projection system and diffusion tensor imaging (DTI) to delineate the human homologue of area prostriata, investigate its functional properties and explore its connectivity with the visual thalamus. We measured BOLD responses with a GE 3T scanner (Excite HDx, GE Medical Systems, Milwaukee, WI) to construct population receptive field (pRF) maps for nine healthy volunteers using conventional retinotopic mapping stimuli over a large field of view (~60°): (i) horizontal and vertical meridian stimulation; (ii) upper, lower, left and right stimulation of the four visual quadrants; and (iii) checkerboard stimuli to map eccentricity. We stimulated the visual cortex using gratings drifting at moderate speeds (38 deg/sec, 0.26 c/deg) and high speeds (571 deg/sec, 0.018 c/deg), identical contrast (50%), temporal frequency (10 Hz) and contrast sensitivity (~500), projected to a large field of view (~60°). Stimuli were viewed monocularly (right eye). Structural connectivity was explored with probabilistic tractography. pRF mapping revealed an eccentricity representation for the most central part (~20°) of the visual field at the most anterior end of the calcarine sulcus, extending into the parieto-occipital sulcus. The position of this area is consistent with the position of prostriata in the marmoset monkey. In addition, DTI and fiber tractography reveal a white matter tract between the pulvinar and area prostriata, with minimal overlap with the pulvinar-V1 tract, suggesting independent connections. The results demonstrate that, unlike the majority of the visual cortex, area prostriata responds more strongly to very fast than moderate-speed motion, and its structural connectivity is consistent with the hypothesis of a V1-independent thalamic input.

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36.3007 Speed modulates the strength of the inhibitory interaction between motion sensors tuned to coarse and fine scales

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The perceived direction of motion of a brief moving fine scale pattern reverses when a static coarse scale pattern is added to it (Henning & Derrington, VR, 1988). This impairment in motion direction discrimination has been explained by the inhibitory interaction between motion sensors tuned to fine and coarse scales. This interaction depends on the particular spatial frequencies mixed, the size of the stimulus, and the relative contrast of the components (Serrano-Pedraza et al., JoV, 2007, 2010, 2013). In this research we wanted to study the effect of speed on the interaction between motion sensors. We measured duration thresholds in a motion direction discrimination task using Bayesian staircases. The stimuli used in the experiment were horizontally drifting vertical-Gabor patches of 4 degrees diameter (2Sxy). Five stimulus configurations were used: 1 c/deg moving, 3 c/deg moving, 1 c/deg moving + 3 c/deg moving, 1 c/deg moving + 3 c/deg static, and 1c/deg static + 3 c/deg moving. We tested five speeds: 0.5, 1, 2, 4, and 8 deg/sec. Results show that for all conditions but 1c/deg static + 3 c/deg moving, duration thresholds decrease with increasing speed. However, in the condition 1 c/deg static + 3 c/deg moving, duration thresholds increase from 0.5 to 2 deg/sec and then reduce with increasing speed. When representing duration thresholds as a function of speed, our results show for the first time that the inhibitory interaction between motion sensors tuned to coarse and fine scales is tuned to speed showing a band-pass tuning function with a maximum between 1-2 deg/sec.

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36.3008 Ipsilateral sensitivity to visual motion is restricted to V5/MT+ in the right cerebral hemisphere

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Previous experiments have demonstrated that transcranial magnetic stimulation (TMS) of human V5/MT+ in the right cerebral hemisphere can induce deficits in visual motion perception in both the contra- and ipsi-lateral visual hemi-fields. However, when TMS is applied to V5/MT+ in the left hemisphere, motion deficits are restricted to the contra-lateral hemi-field (Thakral and Slotnick, 2011). An explanation for this result might lie in differential stimulation of sub-divisions within V5/MT+ across the two hemispheres. V5/MT+ has two major sub-divisions; MT/TO-1 and MST/TO-2. MST/TO-2 contains neurons with large receptive fields (RFs) that

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extend up to 15° into the ipsi-lateral hemi-field. RFs of MT/TO-1 neurons are smaller and do not extend significantly into the ipsi-lateral field. We wanted to re-examine this functional asymmetry between V5/MT+ in the right and left hemispheres and ascertain whether the pattern of motion deficits is dependent upon the extent to which either MT/TO-1 or MST/TO-2 are disrupted by TMS. MT/TO-1 and MST/TO-2 were identified in six subjects using fMRI localisers that directed target points for TMS. Subjects identified the translational direction (up/down) of a threshold level of coherently moving dots presented in either the left or right visual field whilst TMS pulses were applied synchronously with stimulus onset. Application of TMS to MT/TO-1 and MST/TO-2 in the right hemisphere disrupted direction discrimination in both the contra- and ipsi-lateral visual fields, whereas deficits following application of TMS to MT/TO-1 and MST/TO-2 in the left hemisphere were restricted to the contra-lateral visual field. This result suggests an enhanced role for the right hemisphere in processing full-field translational motion, but contrary to our hypothesis, effects differ across hemispheres rather than within sub-divisions of V5/MT+. This corresponds to literature investigating timing differences across the left and right hemispheres (Ffytche et al., 2000), however the reasons for this asymmetry are still unclear.

Acknowledgement: This work is supported by BBSRC grant BB/N003012/1.

Face Perception: Development and experience

Sunday, May 21, 2:45 - 6:45 pm

Poster Session, Banyan Breezeway

36.3009 Development differentially sculpts population receptive fields across human visual cortex

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A fundamental property of neurons in the visual system is that they have receptive fields that process visual information in spatially restricted regions of visual space. Little, however, is known about their development. While high-level visual areas involved in reading and face recognition show a protracted development in humans, it is unknown if this development is associated with changes to receptive fields, and if so, at what stages of the visual hierarchy they occur. To answer these questions, we estimate the population receptive field (pRF) of all voxels in the visual system in 26 typical children (5-12 years) and 26 adults (22-27 years) and compared across age groups. Participants took part in two fMRI experiments: (1) retinotopic mapping with bars containing black and white checkerboards to delineate retinotopic areas and estimate pRFs, and (2) a functional localizer containing faces, words, bodies, places, and objects to map high-level regions. In the ventral stream, we find no significant difference across age groups in polar angle, eccentricity, pRF size, or visual field coverage in areas V1-VO1 (Figure 1A). In contrast, we found differential development of pRFs of face- and word-selective regions across hemispheres. In the right hemisphere, pRFs and coverage in face-selective cortex become more foveally biased from childhood to adulthood, while word-selective cortex becomes less so. In the left hemisphere, this pattern is reversed (Figure 1B). We link this pRF development to behavior, collecting measurements of fixation patterns on faces and words outside the scanner. We find an increased foveal bias on words and faces in adult relative to child participants (Figure 1C). These results thus suggest a differential development of pRF and visual field coverage in face and word selective regions across hemispheres, which may importantly be driven by changes in viewing experience across development.

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36.3010 Does Blocking the Eyebrows with Eyeglasses Disrupt Faces Recognition Performance?

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In this study, we examined how disguises hinder the ability of a person to recognize unfamiliar faces by focusing on how such disguises naturally block facial features. In previous studies, we've found that, surprisingly, both tinted and clear glasses cause an equal disruption in facial recognition (Moniz, Righi, Peissig, & Tarr, 2010). One possible explanation is that both tinted and clear glasses block the eyebrows, which previous studies have shown are important for recognition (Sadr, Jarudi, & Sinha, 2003; Peissig, Goode, & Smith, 2009). The disguises used were tinted glasses that blocked or revealed the eyebrows. We were interested in the effect blocking had on participants' recognition memory. We used images of 48 individuals, shown in color. The same glasses were added to all the images using the program EvoStyler. Twenty-six participants made judgments on 24 faces (e.g., attractive/unattractive, smoker/nonsmoker, etc.) to learn the faces. These learned faces consisted of 8 each of Black, Asian, and Caucasian faces; half the faces were male, and half were female. The faces were always learned with no glasses. The participants were then given an old/new task and were shown 24 new faces (8 of each race, 12 of each sex) along with the 24 faces they learned. All the test faces were shown with glasses, half of which covered the eyebrows, and in the other half of the images the eyebrows were still showing. We found that when blocking the eyebrows, glasses hindered participants' recognition performance by a small amount (78.5% correct for eyebrows revealed, and 73.1% correct for eyebrows concealed). This difference approached significance ($p=0.056$). These results suggest that blocking of the eyebrows with glasses does decrease performance, but this decrease is relatively small. Thus, there are likely to be other features that contribute to the decrease in recognition caused by eyeglasses.

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36.3011 Testing the development of face space in early infancy

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Face space proposes that faces are coded along opponent feature vectors in a multidimensional space. Essentially, the center of face space is defined by an average face that can be modified with experience. It is unclear how and when face space emerges in infancy. Fifty infants (3-12 months old) were tested using a free viewing task. Infants were first familiarized to a face (6 presentations of 5 s) and then presented with two test faces (10 s). Three types of trials were shown after familiarization to a novel face, 1- another novel face versus an average face; 2- the anti-face versus another novel face; 3- two other novel faces. Infants were expected to show greater rebound to the more novel face in the pair, e.g., 1- the novel face, 2- the anti-face, 3- no preference. Analyses revealed a significant effect of trial type, $F(2,45.08) = 4.29$, $p= 0.021$. Greater rebound was found for 1- the novel face (mean = 0.561) and 2- the anti-face (mean = 0.527). Subjects also showed an unexpected identity bias in trial 3, in that they preferred to look at one of the two novel face identities (mean = 0.567) when no preference was predicted. Only for trial 1, however, did the rebound differ significantly from no preference, e.g., 50%, $t(46) = 2.45$, $p= 0.018$. Overall, these data provide some support for an early organization of face space. Infants perceived the average face as the most familiar face, but they failed to show strong evidence for the opponent structure of face space, e.g., greater rebound for the anti-face. There were no significant effects of age, suggesting that a face prototype is functional from an early age and remains stable over the first year, but the opponent structure of face space requires more time to develop.

36.3012 Infant visual exploration strategies predict own-race face discrimination

Ryan Barry-Anwar[1](rbarryanwar@ufl.edu), Trevor Zwaan[1], Lisa Scott[1]; [1]Department of Psychology, College of Liberal Arts and Sciences, University of Florida

Infant scanning patterns within a face predict recognition of own-race faces in infants (Gaither et al., 2012). The present study sought to determine if infants' visual exploration strategies relate to their ability to discriminate faces within own- and other-race groups. Eye tracking measures were recorded while 6-9 month old infants completed a visual paired comparison task that measured discrimination of faces within four racial groups (Caucasian, Asian, African American, and Hispanic). For each trial, infants were familiarized to a single face from one of the groups presented simul-

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taneously on the left and right side of the screen for 15s (Figure 1). Next, the familiarized face appeared alongside a novel same-race face for 10s. Novelty preference was calculated by dividing the duration fixating the novel face by the total duration fixating either face. The number of visual transitions during familiarization within each of the two images (eye to mouth region (1)) and between identical areas across the two images (eye to eye region (2) and mouth to mouth region (3); Figure 1) were calculated. We regressed novelty preference on participant race (Caucasian or biracial), age group (6 or 9 months), visual transitions within the face, eye to eye transitions, and mouth to mouth transitions. The model for Caucasian faces was significant, $F(5,13)= 5.13$, $p=0.02$. Number of transitions between the eye regions of each face predicted the novelty preference at test ($p = 0.007$). As novelty preference increased, the number of eye to eye transitions decreased (Figure 2). The model for other-race faces was not significant (see Fig.2). These results suggest that infants use different visual strategies when comparing own- and other-race faces, and that comparisons between the eye regions of two identical faces predict own-race face discrimination.

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36.3013 The development of own- and other-race face individuation: Evidence from steady-state visual evoked potentials. Lisa Scott[1](lscott@ufl.edu), Ryan Barry-Anwar[1], Trevor Zwaan[1]; [1]Department of Psychology, College of Liberal Arts and Sciences, University of Florida

Prior to 9 months of age, infants can discriminate between both own- and other-race faces using behavioral paradigms (e.g., Kelly, Quinn et al., 2007). However, the neural mechanisms underlying this early discrimination are not well understood. Here we examined adult and 6-month-olds infants' neural discrimination of faces within own- and other-race groups using steady state visual evoked potentials (ssVEP's). Continuous EEG was recorded in a group of Caucasian adults (preliminary n=4) and 6-month-old infants (n=10) while a single face from one of four racial groups (Caucasian, African American, Asian, or Hispanic) was presented at a frequency of 6Hz (the standard) for 20 second trials. Every 5th face was a different individual within the same race (the oddball). In general, a 6Hz response to faces was present for both adults and infants. For adults, an overall oddball response at 1.2Hz (6Hz/5) was also present indicating discrimination of exemplars within race. However, an analysis of the different face groups revealed a significant oddball response for Caucasian ($p< 0.001$) and African American ($p< 0.001$) faces but not for Asian or Hispanic faces (see Figure 1). We hypothesize that increased discrimination of faces within Caucasian and African American face groups are driven by different underlying mechanisms. Inspection of individual infant data revealed that the infants also exhibited an oddball (1.2Hz) response, however the topography of the response varied across infants with some showing peaks occurring over anterior electrode locations and others over posterior electrode locations. These results suggest increased neural variability across infants and within the infant brain and suggests that infants may recruit attentional (anterior) and/or perceptual (posterior) resources when learning to discriminate. Based on the findings with adults, we predict that the neural systems that underlie face discrimination stabilize to primarily posterior regions by adulthood.

Acknowledgement: NSFNational Science Foundation CAREER Award (BCS-1056805)

36.3014 Contribution of internal noise & efficiency to older adults' face discrimination Sarah Creighton[1](creighs@mcmaster.ca), Patrick Bennett[1], Allison Sekuler[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

The mechanisms responsible for age-related declines in face perception are not well understood. Using the classification image (CI) method with sub-sampled faces, Creighton et al. (VSS 2014) showed that, relative to younger adults, older adults made less efficient use of informative face regions. However, many older adults showed no obvious structure in their CIs, suggesting increased internal noise may play a role in decreased performance. To address this issue, we assessed the relative contributions of additive internal noise and efficiency on age-related differences in face discrimination using the equivalent input noise paradigm. Contrast thresholds were measured in a 2 alternative forced-choice face discrimination task in 17 older adults and 14 younger adults with faces presented in varying levels of external noise, and the threshold-vs-noise curves were used to estimate efficiency and equivalent input noise. To facilitate comparison with previous work (e.g., Gold et al., Cog Sci, 2004), thresholds were measured with full faces and sub-sampled faces. For full faces, we observed age-related decreases in efficiency, but no evidence of increased equivalent input noise. For sub-sampled faces, relative to younger adults, older adults showed decreased efficiency and increased equivalent input noise. These results are consistent with those of Creighton et al. (VSS 2014), and support the notion that older adults' lack of obvious structure in their CIs was due partly to a decreased ability to extract diagnostic information in faces and partly to increased additive internal noise. We currently are testing additional subjects who participated in the original CI study to identify the role of individual differences in comparing results across the two methods. In sum, our findings suggest that age-related declines in face discrimination are attributable both to decreased efficiency and, at least in some conditions, to increased additive internal noise.

Acknowledgement: CIHR, CRC

36.3015 Age-related decline in face identification can be trained away, and is explained by horizontal bias. Alexander Elliott[1](alexander_elliott@hotmail.com), Ali Hashemi[1], Sarah Creighton[1], Patrick Bennett[1], Allison Sekuler[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Horizontal structure conveys diagnostic information for face identity (Dakin & Watt, J Vis 2009). Younger adults preferentially rely on this structure for identification (Goffaux & Dakin, Front Psychol 2010), and the extent of this horizontal bias correlates with identification accuracy in younger adults (Pachai et al., Front Psychol 2013). Older adults identify faces less accurately (Konar et al., Vis Res 2013) and exhibit less horizontal bias compared to younger adults, particularly when the diagnostic facial information is not explicitly defined (Sekuler et al., VSS 2014). Here, we examine whether training improves face identification in older adults, and whether enhanced face identification correlates with increased horizontal bias for diagnostic facial structure. Eleven older adults (67-77 years old) trained in a 1-of-10 face identification task for 1440 trials across 3 days. Before and after training, we assessed horizontal bias with orientation-filtered stimuli that preserved target-diagnostic information in 9 orientation bands (full bandwidth 20-180 deg; 20 deg increments) centred on 0 (horizontal) or 90 (vertical) deg. The complimentary, non-filtered orientations contained non-diagnostic facial context created by averaging the 10 faces. Hence, the pre- and post-training test stimuli were face-like in all conditions, but contained diagnostic information only at certain orientations. Training improved accuracy in older adults by an average of 22% (±4.7 SE; range -1–47%). Horizontal bias in older adults increased significantly after training: training improved accuracy significantly more for stimuli containing horizontal diagnostic structure than vertical diagnostic structure. Also, the change in horizontal bias from pre- to post-training was correlated with response accuracy during training ($r=0.66$), and the correlation between overall accuracy with pre- and post-training horizontal bias was 0.30 and 0.75, respectively. Thus, age-related deficits in face recognition are reduced with training, which appears to increase sensitivity to horizontal structure.

Acknowledgement: NSERC, Canada Research Chairs

36.3016 Face diet revealed: A study of daily exposure to faces in adult observers Ipek Oruc[1,2](ipor@mail.ubc.ca), Fakhri Shafai[1,2], Paula Lages[1], Thais Ton[1], Shyam Murthy[1]; [1]Ophthalmology and Visual Sciences, University of British Columbia, [2]Neuroscience

A variety of well-established phenomena in face perception are often explained based on the 'face diet'—the contents of daily exposure to faces. For example, the face inversion effect and the other-race effect are believed to stem from minimal exposure to inverted and other-race faces, respectively. Face perception involves a protracted development period and remains malleable well into adulthood (Germine, Duchaine, Nakayama, 2011; Rhodes et al. 2011). Previous studies focused on the face diet in infancy (Jayaraman, Fausey, Smith, 2015; Sugden, Mohamed-Ali, Moulson, 2013). We present the first report on the face diet of adults (N=29) via a head-mounted camera. Our aim was to 1) provide empirical evidence for widely-believed assumptions such as the predominance of own-race and upright faces; 2) examine unknown aspects of the face diet regarding gender, familiarity, and pose; 3) test whether visual experience with faces occurs most often at close social distances, a hypothesis that was borne out of previous work (Oruc, Barton, 2010; Yang, Shafai, Oruc, 2014). Out of the

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25,691 recorded frames (>214 hours of footage), 7475 faces were detected and annotated for gender, ethnicity, size, familiarity and pose. No inverted faces and no differences between exposure to faces of either gender were observed. Majority of faces were own-race (>85%). Faces were most frequently seen in the three-quarters pose, followed by frontal, and then by profile. Over 75% of faces were familiar, reflecting the longer periods of interaction with familiar individuals in contrast to brief encounters with strangers. Seventy-three percent of all faces were viewed from 1.5 m or closer, peaking at 89 cm (median), corresponding to a face size of about 8-9 degrees visual angle. These results confirm widely-accepted assumptions regarding the contents of the face diet and furthermore provide a potential explanation for effects of size in face recognition performance.

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36.3017 **Qualitative Differences Between Professional Forensic Face Examiners and Untrained People in Person Recognition Are Revealed by Item Analysis** Ying Hu[1](yxh144230@utdallas.edu), Kelsey Jackson[1], Amy Yates[2], David White[3], P. Jonathon Phillips[2], Alice O'Toole[1]; [1]The University of Texas at Dallas, U.S.A, [2]National Institute of Standards and Technology, U.S.A., [3]University of New South Wales, Australia

Professional forensic face examiners surpass untrained participants on various challenging face identity-matching tasks (White et al., 2015). We posited that qualitative differences between groups in White et al. would be revealed by examining performance across groups at the level of stimulus items. We developed a novel item-based analysis of the face- and body-informative stimuli from White et al. (2015), which were selected based on human and computer performance from previous work (Rice et al., 2013). For each item, we recorded the participant group with the highest accuracy as that item's "winner". Next, a wisdom-of-the-crowds approach was implemented by fusing/averaging item responses within each group, incrementally adding participants to amplify the item effects. The distribution of wins across groups for face- versus body-informative items differed strongly in the fully fused (i.e., all group participants averaged) sample (Chi-squared = 41.97, df = 2, $p < .01$) with examiners winning 70% of the face-informative cases, but only 32% of body-informative cases. A strong dissociation was seen also for same- versus different-identity items in the fully fused case (Chi-squared = 11.28, df = 2, $p < .01$). Although examiner superiority increased with fusion for same- and different-identity items, the increase for different-identities was striking, with examiner wins increasing from 31% in 1-participant samples to 78.5% in the fully fused sample. Criterion analyses eliminated response bias as a full account of the difference. In summary, professional forensic face examiners were highly skilled in using information from the internal face for identification, but failed to effectively use identity cues from the body. They were also more effective at rejecting different-identity items than at confirming same-identity matches. The use of the novel item analysis with wisdom-of-the-crowds fusion proved useful as a tool for exploring strategic differences between examiners and untrained participants.

Acknowledgement: National Institute of Justice National Institute of Standards and Technology

36.3018 **How does representation of faces change with increasing familiarity?** Mintao Zhao[1](mintao.zhao@tuebingen.mpg.de), Duangkamol Srismith[1], Isabelle Bülthoff[1]; [1]Max Planck Institute for Biological Cybernetics

It is well established that familiar and unfamiliar faces are processed differently, in terms of both behavioural and neural responses. Although these differences indicate that representation of faces changes when faces become more and more familiar, how familiar and unfamiliar faces are represented in memory and how increasing familiarity changes face representation remain unclear. Here we investigated how faces are represented when participants saw them for the first time (i.e., unfamiliar faces), when participants had developed visual familiarity with them (i.e., visually familiar faces), and when participants knew the faces very well (i.e., personally familiar faces). Participants were shown an array of facial morphs varying from highly anti-caricatured (-50%) to highly caricatured (+50%), and were asked to select one matching the original face of the person best. The results showed that, for unfamiliar faces, participants' response frequency was highest for the highly anti-caricatured faces (-50%), and decreased when faces became more and more caricatured. For personally familiar faces, participants selected the original faces most often, and the further away a facial morph was from the original face, the less likely it was selected. Responses to visually familiar faces differed from responses to both unfamiliar and very familiar faces and can be described as a transition between them. These results indicate that unfamiliar faces are initially represented with a bias towards the facial norm, whereas personally familiar faces are represented veridically. Importantly, these data demonstrate that face representation shifts in face space with increasing familiarity. The more familiar a face is, the more its corresponding representation shifts from a location near the facial norm (i.e. anti-caricatured) to its veridical location in face space.

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36.3019 **The Effect of Home-Schooling on Face Processing Ability** Lindsey Short[1](lshort@redeemer.ca), Benjamin Balas[2], Cassandra Wilson[1], Matthew Linzel[1]; [1]Department of Psychology, Redeemer University College, [2]Department of Psychology, North Dakota State University

Recent research (e.g., Balas & Saville, 2015) has demonstrated that individuals from small communities show impoverished face recognition relative to those from large communities, suggesting that the number of faces to which one is exposed may have a measurable effect on face processing abilities. In the present study, we sought to extend these findings by examining a second factor that influences the population of faces to which one is exposed during childhood: educational setting. In particular, we examined whether participants who were homeschooled (n = 22) show reduced performance relative to non-homeschoolers (n = 26) on two measures used to characterize face recognition ability: the Cambridge Face Memory Test (Duchaine & Nakayama, 2006) and an identity sorting task (Jenkins et al., 2011) in which participants sort 40 photographs of two unfamiliar identities (20 photographs/model) into the number of identities they believe are present. On the CFMT, there was no effect of educational setting, $p = .82$; however, on the sorting task, participants who were homeschooled showed significant deficits. Relative to non-homeschoolers, participants who were homeschooled perceived more identities, $p = .03$, and showed reduced discriminability, $p = .007$, when forming identity-specific piles in the sorting task. Such results suggest that reduced exposure to faces early in life as a function of homeschooling may have lasting effects on the face processing system, particularly with regard to perceptions of within-person variability.

36.3020 **Modulation of Expression on the Generalization Gradient of Pose in Face Learning and Recognition** Becky Chen[1,2,3](becky00635@gmail.com), Gary Shyi[1,2,3]; [1]Department of Psychology, National Chung Cheng University, Chiayi, Taiwan, [2]Centre for Research in Cognitive Sciences, National Chung Cheng University, Chiayi, Taiwan , [3]Advanced Institute of Manufacturing with High-tech Innovations, National Chung Cheng University, Chiayi, Taiwan

All faces start anew and how novel faces can be transformed into perceptually familiar ones, overcoming variations in lighting, pose, and expression, among others, has been an important research question awaiting for satisfactorily answers. Our previous studies have demonstrated that multiple exposures coupled with sufficient variation in either expression or pose can lead to robust recognition and significant generalization, transforming novel faces into familiar ones (Shyi & He, 2011; Shyi & Lin, 2014; Cheng & Shyi, 2014). However, whether and how expression and pose can jointly affect face learning and recognition is unknown. In the present study, we examined this issue in two experiments. In Experiment 1, using 3-D face models built from 2-D images, we largely replicated our previous findings, and showed that faces that were learned with multiple expressions can lead to better generalization in recognition than those learned with single expressions. In Experiment 2, we examined how the generalization gradient in terms of angular disparity in pose between learning and test may be modulated by facial expressions. The results revealed that happy faces yielded a gradient similar to that of neutral faces. Specifically, as angular disparity between learning and test increased, performance in recognition and generalization decreased. In contrast, sad faces yielded a relatively stable generalization gradient regardless of variation in angular disparity. Taken together, these results suggest that positive and negative expressions can have pervasively differential effects on the generalization gradient of pose in face learning and recognition.

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Face Perception: Disorders

Sunday, May 21, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

36.3021 What is the Perceptual Deficit in Developmental Prosopagnosia?

Irving Biederman[1,2](bieder@usc.edu), Eshed Margalit[2,4], Rafael Maarek[3], Emily Meschke[2], Bryan Shilowich[1]; [1]Department of Psychology, University of Southern California, [2]Program in Neuroscience, University of Southern California, [3]Department of Biomedical engineering, University of Southern California , [4]Program in Neuroscience, Stanford University

Developmental prosopagnosics (DPs) have otherwise normal vision and generally show normal recognition of non-face visual entities, such as objects and scenes. They do suffer, in comparison to controls, on a wide range of standard face recognition tests that define DP. As simple as these tests appear at first perusal, none make it clear just what it is that a DP cannot do visually. Moreover, as these tests typically include some aspect of memory or transformation, it is unclear if there is even a purely visual deficit. Method. To assess whether a perceptual deficit underlies DP, subjects performed simple simultaneous match-to-sample tests of triangular arrays of three faces, three blobs with face texture, or three geons (Fig. 1). The upper stimulus was an exact match to one of the two lower stimuli, with the foil differing metrically from the match. The similarity of the differences between foils and matching stimuli was scaled to be equal across the different stimulus classes, according to a model of V1 simple cell similarity. Matching and foil faces differed in the height of the cheekbones and the vertical distance between eyes, nose, and mouth. These variations produced differences between the faces that could not be readily articulated by the subjects. The diagonal relation between sample and matching stimuli defeated a simple horizontal or vertical alignment strategy in which differences in local pixel clusters or contour features could be employed to detect the distractor. Results and Conclusion. DPs performed worse than controls on both the face and blob tasks but not the geon task. Moreover, accuracy (percent correct) on the face task was significantly correlated with performance on a variety of standardized tests for prosopagnosia (Table 1). A deficit in the simultaneous discrimination of small metric differences of complex, biologically appearing stimuli may thus underlie DP.

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36.3022 Delayed processing of global shape in developmental prosopagnosia

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There is accumulating evidence suggesting that the central deficit in developmental prosopagnosia (DP), a disorder characterized by lifelong difficulties with face recognition, concerns impaired holistic processing. Some of this evidence comes from studies using Navon's paradigm where individuals with DP show a greater local/reduced global bias compared with control subjects. However, it has not been established precisely what gives rise to this altered processing bias: Is it a reduced global precedence effect, changes in susceptibility to interference effects, or both? To examine this, we tested 10 subjects with DP and 20 matched controls on Navon's paradigm with compound letters. We also assessed visual attention and object recognition in both groups. The DP-group exhibited a reduced global precedence effect compared with the control group. They were also impaired recognizing silhouette and fragmented objects. In contrast, their visual short-term memory capacity, visual processing speed, efficiency of top-down selectivity, and spatial allocation of attentional resources were within the normal range. This suggests that the reduced global bias effect found in the DP-sample reflects a perceptual rather than an attentional deficit. To examine whether the reduction in the global precedence effect was systematically related to the face recognition impairment of the DPs we examined the correlation between the magnitude of the global precedence effect and performance on the Cambridge Face Memory Test. This yielded a positive correlation ($r = .63$, $p = .026$ one-tailed); the lower the global bias the poorer the face recognition performance. Similar relationships were observed for object recognition with silhouettes ($r = .72$, $p = .022$ one-tailed) and fragmented forms ($r = .72$, $p = .01$ one-tailed). We conclude that the DPs' impaired performance in all three domains (Navon, face and object recognition) is related to the same dysfunction; delayed derivation of global shape information.

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36.3023 Attentional modulation in the face network in participants with normal face processing and developmental prosopagnosia

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It has been suggested the ventral face areas, including occipital face area (OFA) and fusiform face area (FFA), process invariant aspects of faces such as identity while the dorsal areas, including the face-selective areas in posterior superior temporal sulcus (pSTS-FA) and in inferior frontal gyrus (IFG-FA), represent changeable aspects such as viewpoints and expressions. To investigate this division of labor, we manipulated which face aspect participants attended to while they were scanned. In addition, by testing developmental prosopagnosia participants (DPs) with the same task, we examined whether deficits in attentional modulation contribute to their face impairments. We first used a dynamic localizer to identify category-selective areas in 16 participants with normal face processing and 12 DPs. Next they performed a one-back task in which they selectively attended to either face identity, expression, or viewpoint. In normal participants, accuracy for identity and expression was comparable while accuracy for viewpoint was significantly better. Areas in the left and right hemisphere showed similar responses. In the OFA, responses in the three conditions were comparable. In the FFA, responses to identity and expression were stronger than to viewpoint. In the pSTS-FA, expression elicited the strongest responses and face view elicited stronger responses than identity. In IFG-FA, response to expression was the strongest, followed by identity, and then face view. DPs and controls showed comparable accuracy for expression and viewpoint judgments, but DPs were significantly worse than controls for identity judgments. Neurally, DPs showed comparable task modulation as controls across all the areas. In summary, face-selective areas show different response patterns to attentional modulations. Some of these patterns are consistent with the ventral/dorsal and invariant/changeable framework mentioned above, but some are not. In addition, normal attentional modulation effects in DPs indicate their impaired face processing does not result from deficits with face attentional modulation.

36.3024 Retinotopic Specificity of Face Encoding in Neurotypicals and Developmental Prosopagnosics

Matthew Peterson[1](mfpeters@mit.edu), Harris Hoke[1], Ian Zaun[1], Brad Duchaine[2], Nancy Kanwisher[1]; [1]Massachusetts Institute of Technology, [2]Dartmouth College

Recent behavioral (Peterson & Eckstein, 2012, 2013) and neuroimaging (Henriksson, Mur & Kriegeskorte, 2015; de Haas et al., 2016) evidence suggests that neurotypicals (NT) encode faces in a retinotopically-specific fashion: Subjects perform best recognizing familiar faces at their personal "preferred looking position" (Peterson et al., 2016). Here we ask three questions: 1) Do individuals have similar preferred looking positions for both faces and non-face objects? 2) Does the tight relationship between preferred face-looking position and face recognition accuracy reflect either a fundamental difference in representational capacity for faces at different retinotopic positions, or an advantage for matching the retinotopic position of a face at encoding and test? 3) Is face-fixation behavior or its relationship to performance different in developmental prosopagnosia (DP)? We assessed the specificity of individual differences in eye movements and performance for face recognition in 15 NT and 11 DP subjects. In three tasks, subjects were free to move their eyes as they recognized celebrities (ID), cars (CAR), and expressions (EXP). In a fourth task, subjects decided whether two sequential images of unfamiliar faces showed the same person while maintaining fixation at each of four face-positions (SD). We found that DPs were selectively impaired at face identification (ID, SD) but not at object (CAR) or expression (EXP) recognition. Identification deficits in DPs could not be explained by eye movements; compared to NTs, DPs showed no significant difference in the location (mean) or consistency (variance) of initial eye movements. Critically, individual differences in the locations of NT face-fixations were: 1) Uncorrelated with car-fixations (face-specific), and 2) Strongly predictive of face recognition ability across retinotopic positions (i.e., upper-face lookers performed best fixating the eyes, lower-face look-

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ers performed best fixating the mouth), suggesting that individuals' face representations are tuned to the individual-specific retinotopic positions at which faces appear during natural, real-world behavior.

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36.3025 The face-inversion effect in developmental prosopagnosia

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The face-inversion effect (FIE) refers to the observation that inversion impairs the processing of faces disproportionally more than other mono-oriented objects. The FIE has further been found to be abolished or reduced in acquired prosopagnosia. Whether this is also true of developmental prosopagnosia (DP) is less clear with reports of normal FIEs, reduced/abolished FIEs or even paradoxical FIEs (better performance with inverted than upright faces). We compared FIEs in 17 DPs and 17 matched controls by contrasting performance on the Cambridge Face and Car Memory Tests with upright and inverted stimuli. The DP-group showed a reliable inversion effect for faces which was nevertheless significantly reduced compared with that seen in the control-group. In comparison, there was no reliable group difference for cars. The FIE was reliable in the control- but not the DP-group and it was reliably larger in the control- than in the DP-group (interaction effect), suggesting an abolishment of the FIE in the DP-group. On a single-case level 3 DPs showed a (classical) dissociation with the difference between upright and inverted faces being smaller than that observed in the control-group. In all three cases performance was better, although not reliably better, with inverted faces. Two other DPs showed a (classical) dissociation with the difference between upright and inverted cars being larger than that observed in the control-group. In both cases, performance was significantly better with upright cars. Finally, of the three DPs exhibiting a reduced inversion effect for faces, only one showed a (classical) dissociation with regards to the FIE, with the difference between upright and inverted faces on the one hand and the difference between upright and inverted cars on the other deviating significantly from the control-group. The finding of reduced/abolished but no paradoxical FIEs in DP mirrors findings in acquired prosopagnosia.

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36.3026 Ensemble Coding of Face Identity in Congenital Prosopagnosia

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When viewing groups of faces, people with typical face recognition are able to recognise individuals, as well as extract the average identity of the group, known as an 'ensemble' representation. It is currently uncertain whether dissociable processes underlie these two kinds of representations. People with congenital prosopagnosia (CP) have specific difficulties recognising individual's faces but it is currently unclear whether they also have difficulty extracting ensemble representations. Leib and colleagues (2012, Neuropsychologia) argued that ensemble coding of face identity was unimpaired in CPs (N = 4), consistent with the view that individual and ensemble processes may be dissociable. However, CPs in this study could have used non-identity, image-based strategies. We re-examined ensemble coding of identity in CP using a task that measured both individual recognition and ensemble coding. Participants were shown groups of faces and subsequently asked to decide whether target faces had been present in this group. Targets were either single faces (exemplars) or morphs of a group of faces (averages). Importantly, we could rule-out use of image-based strategies because both image- and identity-based versions were included. Target faces were either the same image (identical photograph) or same person (different photographs) respectively. Ensemble coding was measured by the extent to which group averages were endorsed as group members despite never being seen. CPs (N = 11) showed ensemble coding for both same-image and identity-based conditions, indicating that CPs do show identity-based ensemble coding. However, ensemble coding in both conditions was significantly weaker than for typical recognisers (N = 20). Recognition of individual faces was also weaker for the CPs. Overall our results indicate that ensemble coding of facial identity is weaker in CPs, consistent with their poor individual face recognition skills. Therefore, we found no evidence of a dissociation between individual recognition and identity ensemble coding.

Acknowledgement: Australian Research Council Centre of Excellence in Cognition and its Disorders, University of Western Australia, Crawley, Australia

36.3027 PERCEPTUAL LEARNING OF FACES: A REHABILITATIVE STUDY OF DEVELOPMENTAL PROSOPAGNOSIA

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In recent years, several attempts have been made to improve face recognition in developmental prosopagnosia. These efforts have often resulted in training effects that are either not long lasting, or do not generalize to novel viewpoints, expressions, or identities. We used a perceptual learning approach to train face recognition in a group of 7 participants with developmental prosopagnosia. Four completed the 11-week training program first, followed by an 11-week non-training period and three completed an 11-week control task followed by the training program. On each trial of the training program, participants selected which of two test faces appeared most similar to a simultaneously presented target face. A staircase procedure was used to ensure that each participant was training at an individually appropriate level—as performance improved, faces become more similar, and when performance declined, faces became less similar. With each week of training, variation across viewpoint and expression were gradually introduced. Performance on post-tests improved significantly more during the training period than non-training period for both trained faces ($p< 0.001$) and untrained faces ($p< 0.05$), suggesting that the program produced effects that generalized across novel viewpoints, expressions, and identities. At the individual level, some participants reported improvements in their everyday experiences as well. In sum, perceptually learning may be an effective approach for improving face recognition in developmental prosopagnosia.

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36.3028 Perceptual learning of faces: a rehabilitative study of acquired prosopagnosia

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Background: Despite many studies of acquired prosopagnosia, there have been only a few attempts at its rehabilitation, all in single-cases, with a variety of mnemonic or perceptual approaches, and of variable efficacy. Method: In a cohort with acquired prosopagnosia, we evaluated a perceptual learning program that incorporated variations in view and expression, which was aimed at training perceptual stages of face processing with an emphasis on ecological validity. Ten patients undertook an 11-week face training program and an 11-week control task, as well as functional MRI resting state scans at three time-points: baseline, after training, and after a control task. Training required shape discrimination between morphed facial images, whose similarity was manipulated by a staircase procedure to keep training near a perceptual threshold. Training progressed from blocks of neutral faces in frontal view through increasing variations in view and expression. Results: While the control task did not change perception, training improved perceptual sensitivity for the trained faces and generalized to new untrained expressions and views of these faces. There was also a significant transfer to new faces. Benefits were maintained over a 3-month period. Training efficacy was greater for those

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with more perceptual deficits at baseline. There was increased functional connectivity between the left OFA and bilateral STS after training but not after the control task. Conclusion: We conclude that perceptual learning can lead to persistent improvements in face discrimination in acquired prosopagnosia, and that training faces at the level of three-dimensional expression-invariant representations results in increased connectivity between OFA and STS in acquired prosopagnosics.

36.3029 Developmental dyslexia and potential deficits of experience-driven visual processing Heida Sigurdardottir[1](heidamaria@gmail.com), Liv Fridriksdottir[1], Sigridur Gudjonsdottir[1], Árni Kristjánsson[1]; [1]Department of Psychology, University of Iceland

Previous research suggests that dyslexic readers can have subtle problems with recognizing familiar non-word objects such as faces. Such deficits have not always been observed, however, and the potential roots of the problem are unclear. In two experiments, we sought to firmly establish the existence and specificity of this problem. We administered a perceptual face matching task (with minimal memory requirements) to participants with and without a history of reading problems (total N=105). As the task required the discrimination and matching of previously unknown faces across viewpoint, rendered with identical texture, participants were forced to rely on fine-grained visual discrimination of high-level shape cues. Face matching performance on this task was found to predict reading problems, both in a general sample of university students (experiment 1) as well as in a sample of matched dyslexic and typical readers (experiment 2). Difficulties with face matching were consistently found to predict dyslexia over and above that of matching novel objects (YUFOs), matching noise patterns that shared low-level visual properties with faces (scrambled faces), and classifying stimuli as belonging to a face (face/no face). The relationship between dyslexia and face matching problems also was not accounted for by measures of ADHD (typically comorbid with dyslexia). Our results show that people with dyslexia do not have general visual problems, not even general problems with objects, or faces. Instead, their problems could be mainly restricted to individuating visually homogeneous objects, such as faces and words, with which people have had prior experience.

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36.3030 Typical integration of emotion cues from the face and body in Autism Spectrum Disorder Rebecca Brewer[1](rebecca.1.brewer@kcl.ac.uk), Federica Biotti[2], Geoffrey Bird[3], Richard Cook[2]; [1]Royal Holloway, University of London, [2]City, University of London, [3]University of Oxford

Contextual cues derived from body postures bias how typical observers categorise facial emotion; the same facial expression may be perceived as anger or disgust when aligned with angry and disgusted body postures. This integration is thought to occur automatically, despite instructions to disregard body context, and influence the early visual processing of others. In typical observers, integration processes may emerge in response to the covariation of facial and bodily expressions. However, it is widely thought that individuals with Autism Spectrum Disorder (ASD) struggle to integrate information from disparate visual regions to form unitary percepts. This local processing style may leave them less susceptible to visual illusions induced by context. The current study therefore investigated whether individuals with ASD exhibit diminished integration of emotion cues extracted from faces and bodies. Individuals with ASD (N = 19) and typical controls (N=27) completed a binary expression classification task. Facial stimuli were drawn from a morph continuum created by blending two images of the same actor expressing disgust and anger. The body contexts depicted the same actor posing anger and disgusted postures. In the baseline no-context condition, the facial target was presented in isolation. In the two context conditions, the facial target was accompanied by angry and disgusted body postures. Following stimulus offset, participants were prompted to categorize the facial emotion as either 'Disgust' or 'Anger'. Participants were explicitly instructed to disregard the body context. Contextual modulation was inferred from a shift in the resulting psychometric functions. Contrary to our prediction, observers with ASD showed typical integration of emotion cues from the face and body. Correlation analyses indicated a strong relationship between the ability to categorise emotion when faces were presented in isolation, and susceptibility to contextual influence; body cues were relied upon to a greater extent in individuals with poorer facial emotion recognition.

36.3031 Eye gaze following is an autism endophenotype for males but not females Elisabeth Whyte[1](emv131@psu.edu), K. Suzanne Scherf[1]; [1]Department of Psychology, The Pennsylvania State University

Autism is a highly heritable developmental disorder. Endophenotypes are heritable sub-clinical traits associated with the expression of a disorder in the general population. One of the core symptoms, and potential endophenotypes of autism, is difficulty processing eye gaze cues. However, the specific nature of this difficulty is still not well understood. Here, we investigated whether a part of this difficulty is related to impairments in understanding the referential nature of eye gaze; that is following the trajectory of gaze to determine what a person is looking at. We investigated whether individuals who are typically developing (TD), but high in autism traits, have more difficulty tracking eye gaze than do those who are TD with low autism traits. The participants included 120 TD young adults who scored ±1 SD beyond the mean of 2257 young adults screened on the Autism Quotient. We included equal numbers of male and female participants in the high and low trait groups. The eye gaze following task included static images of a person looking at one of many possible objects in a scene. Participants selected one of four labels that identified the target gazed-at object. There was a significant participant sex x autistic trait group interaction ($p < .05$). Males with high autism traits had lower gaze following accuracy than both males with low autism traits and females with high autism traits ($p < .05$). For females, there was no difference in performance between the high and low autism trait groups. In addition, scores on gaze following were related to face recognition behavior. These findings indicate that impaired gaze following is a potential endophenotype of autism, but only for males, which is consistent with the notion that autism symptoms and endopheynotypes may manifest differently in females.

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Development: Atypical development

Sunday, May 21, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

36.3032 Reading speed during a mesopic visual acuity task Nancy Coletta[1](colettan@neco.edu), Lenna Walker[1], Fuensanta Vera-Diaz[1]; [1]New England College of Optometry, Boston MA

Corrected myopes demonstrate reduced visual acuity and less stable fixational eye movements under mesopic conditions, compared to subjects without refractive error (Coletta et al., ARVO, 2007; Coletta et al., ARVO, 2016; FVM, 2016). Reduced acuity in myopia may be related to fixation instability, perhaps analogous to amblyopia, where less stable eye movements are associated with reductions in acuity and reading speed (Kanonidou et al., IOVS, 2010). In this study, we examined whether a subject's acuity and fixation stability were related to the time they spent to read an acuity line. Measurements were made on 31 subjects, mean age 25.7 years. Spherical equivalent refractions ranged from +2.25 to -10.88 D. Mesopic (0.28 cd/m2) and photopic (325 cd/m2) acuity was measured with high contrast letters, five per line, while eye position was recorded at 500 Hz using an EyeLink 1000 video-based eye tracker. Fixations were analyzed for letter sizes corresponding to the mesopic and photopic acuity limits. Fixation stability is reported as the bivariate contour ellipse area (BCEA), taken over a 2-sec interval, representing the area of fixation for 68% of the time. At the mesopic condition, subjects who took longer to read a line at their acuity limit had higher mesopic acuity ($p=0.001$) and smaller loss of acuity relative to their photopic acuity ($p=0.025$). However, there was no correlation between reading duration at the photopic acuity limit and photopic acuity ($p>0.05$), nor between reading duration and refractive error ($p>0.05$). When the mesopic acuity letter size was read at the photopic light level, BCEA decreased with increasing reading duration ($p=0.032$). For an acuity task in dim light, reading speed was correlated with acuity, but in an opposite direction to that reported for amblyopia; slower reading speed was associated instead with increased visual performance. Reading speed was not associated with refractive error.

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36.3033 White matter changes following early loss of one eye extend beyond the primary visual pathway

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Long-term morphological changes following early (< 2 years of age) monocular enucleation (surgical removal of an eye) are present in adult subcortical and cortical visual, auditory, and multisensory regions. Previously we reported increased radial diffusivity (RD) in the right optic radiation of people with one eye, and an absence of the hemispheric asymmetries that exist in controls. In an attempt to determine whether these structural connectivity changes extend to other related white matter tracts, we investigated how the early loss of one eye affects the development of connectivity in: 1) tracts connecting primary visual cortex (V1) to lateral geniculate nucleus (LGN), 2) occipito-callosal connections between left and right V1, 3) auditory radiations, and 4) cortico-cortical projections from primary auditory cortex (A1) to V1. Diffusion-weighted images were acquired for all participants and probabilistic tractography was used to reconstruct the tracts of interest. Average values for fractional anisotropy (FA), mean diffusivity (MD), axial diffusivity (AD), and RD were extracted bilaterally. In contrast to the optic radiations, the V1-LGN projection in people with one eye was unchanged, compared to controls. However, a significant reduction in FA was observed in the right-to-left V1-V1 projection of the patient group. In both the auditory radiations and A1-V1 tracts, people with one eye did not demonstrate the significant leftward asymmetries that were found in controls. These findings indicate microstructural changes to white matter in people with one eye that extend beyond the primary visual pathway to include interhemispheric, auditory, and multisensory tracts. The lack of asymmetries in the auditory and audiovisual connections may reflect adaptive compensation for the loss of one eye in these sensory modalities, consistent with previous behavioural findings. Overall, these results suggest that early monocular enucleation has distal effects on white matter structure both within the visual system and in other sensory systems.

36.3034 The impact of blindness onset on the connectivity profile of the occipital cortex.

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Resting state functional connectivity (rs-FC) has been widely used to investigate the functional (re)organization of the "visual" cortex in blind people. However, discrepant results have emerged with some studies pointing to massive changes in the connectivity profile of occipital regions in blind individuals while other studies showing similar pattern of occipital connectivity in the blind and the sighted. Moreover, the impact of the onset of blindness on these measures remains poorly understood. This question is however crucial to understand if there is a sensitive period in development for reorganizing occipital networks. In this study we investigated the functional connectivity changes between occipital regions and the rest of the brain in early blind (EB), late blind (LB), and their matched controls using fMRI data acquired at rest. We relied on a bootstrap Analysis of Stable Clusters (BASC) to subdivide the brain into meaningful functional parcels. Whereas both blind groups showed reorganization of the connectivity profile of the occipital cortex, these connectivity changes were more much more extended in early blind individuals. We demonstrate that certain connectivity changes occur regardless of the blindness onset, while others being specific to early or late blindness. These results were further supported by using multivariate pattern classification showing highly significant classification rate of individuals to their respective groups based on the connectivity fingerprint of their occipital regions. However, we also observed certain sub-regions within the ventral occipital cortex (e.g. PPA) that show a similar connectivity profile across all groups. All together, our data suggests regions-specific impacts of blindness onset on the connectivity architecture of the occipital cortex.

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36.3035 Influence of visual cortical GABA concentration on perceptual suppression and binocular summation in amblyopia

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Amblyopia is characterized by reduced visual acuity due to abnormal early visual experience and is often accompanied by suppression of signals from the amblyopic eye. Recent studies indicate a role for intracortical GABAergic inhibition in amblyopic suppression as well as a link between occipital GABA levels and fMRI visual cortical response amplitudes in healthy individuals. To better understand the relationships among behavioral suppression, GABA, and visual responses, we measured several types of perceptual suppression, visual cortical GABA levels with magnetic resonance spectroscopy (MRS), and fMRI response amplitudes in amblyopes and healthy controls. Specifically, we obtained the magnitude of surround suppression, overlay suppression, and interocular suppression for each participant using well-established psychophysical approaches. Additionally, we recorded fMRI activity in retinotopically-defined early visual cortical areas for four stimulus conditions: binocular, dichoptic (different stimuli in both eyes), and monocular stimulation of either the amblyopic/non-dominant or non-amblyopic/dominant eye. Finally, MRS was performed without visual stimulation to measure resting GABA concentration in bilateral occipital cortex. As expected, we found increased surround suppression in amblyopes when the target was presented to the amblyopic eye and the surround to the non-amblyopic eye, relative to the reverse stimulus configuration and to interocular surround suppression in controls. We quantified binocular summation of fMRI responses by computing the difference between binocular versus monocular and between binocular versus dichoptic response amplitudes. Amblyopes exhibited less fMRI binocular summation than controls for both metrics, and these measures of binocular summation were inversely correlated with visual cortical GABA concentration. Surprisingly, especially given our findings of increased perceptual suppression in amblyopia, visual cortical GABA levels were significantly lower in amblyopes than controls. Ongoing analyses are focused on correlating behavioral metrics of interocular interactions and perceptual suppression obtained from psychophysical data with visual cortical GABA levels and with fMRI response amplitudes in visual cortex.

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36.3036 A speed-acuity test to determine delays in visual processing: normative data and application in children with visual impairments

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During ophthalmic examination visual processing speed is not taken into account. However, there are children who experience problems in daily life, which appear to be caused by slowed visual perception. At present, there are no clinical tests which allow testing of visual acuity and processing speed simultaneously. Our aim was to develop such a test to quantify delays in visual processing and to collect normative data for children between 5 and 12 years. Additionally, we applied the test in children with visual impairments (VI) to assess their visual processing speed. 104 children with normal vision (9.4±2.0 years) and 52 children with VI (8.4±1.8 years) performed the speed-acuity test. The test consisted of 2x90 trials and they had to indicate as fast and accurate as possible on which side the opening of a Landolt-C was located using button presses. Nine sizes of the Landolt-C were used, sizes ranged from below visual acuity threshold to at least 0.6 LogMAR above visual acuity threshold. The drift-diffusion model was used to analyse the results. This decision-making model assumes that the brain accumulates (noisy) sensory evidence over time until the 'evidence scores' reach a decision boundary. The normative data revealed that the acuity thresholds obtained with the new test are comparable to those obtained with the Freiburg visual acuity test. Additionally, the results showed that optotype-size has a significant influence on the reaction time. The reaction times decrease as optotype-size increases until they reach a minimum. The drift-diffusion model can account for these results. Furthermore, as children grow older they become faster. A substantial number of children with VI had slower visual processing compared to the normative data. In conclusion, the speed-acuity test is an effective tool to determine impairments in visual acuity and processing speed in clinical populations.

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36.3037 **Reading Ability of Children Treated for Amblyopia** Deborah Giaschi[1](giaschi@interchange.ubc.ca), Marita Partanen[2], Laveniya Kugathasan[1], Violet Chu[1], Christopher Lyons[1]; [1]Department of Ophthalmology and Visual Sciences, University of British Columbia, [2]Department of Educational and Counselling Psychology, and Special Education, University of British Columbia

There are previous reports of compromised reading ability in children with amblyopia, but standardized psychoeducational tests have not been used. Standardized tests are normed with a large sample size and are important for assessing the practical consequences of poor reading ability, such as eligibility for reading supports at school. It is also not clear how amblyopia treatment impacts reading ability. Thus, the goal of this study was to use standardized tests to compare binocular reading performance in children treated for amblyopia to that of a large normative sample, as well as to the types of control groups used in previous studies. Children (7-17 years, M = 11.94 years) treated for strabismic or anisometropic amblyopia (N=11) were compared to children treated for strabismus without amblyopia (N=8) and to control children with healthy vision (N=43). Visual acuity (near and distance), intellectual functioning (WJ III COG), single-word reading (TOWRE 2) and paragraph reading (GORT 5) were assessed. The control group performed significantly better than the amblyopic and strabismic groups on both reading tasks, however, mean performance was within the average range for all groups. While mean scores were in the average range, there were 6 children (4 with amblyopia; 2 with strabismus) who performed below average (< 16th percentile) on at least one reading task. Although all children with amblyopia completed occlusion therapy, some still had visual acuity above 0.2 LogMAR, but reading scores were not correlated with visual acuity. Finally, all children had at least average intellectual functioning. Using standardized tests, we found poorer reading performance in children with amblyopia compared to age-matched controls, and several children read at a level that might benefit from reading supports at school. A similar pattern of performance was observed in children with strabismus without amblyopia, suggesting both strabismus and amblyopia can disrupt reading ability.

36.3038 **Superior Abilities to Focus Visual Attention and Pupil Dynamics are linked with Broader Autism Traits** Vanessa Troiani[1](troiani@mail.med.upenn.edu), Antoinette DiCriscio[1]; [1]Geisinger-Bucknell Autism & Developmental Medicine Institute

Introduction: Aberrant sensory processing, especially in vision, may underlie many of the behaviors observed in autism. While atypical focusing of spatial attention has been associated with an autism diagnosis, the quantitative relationship between atypical spatial attention and autism traits that extend into the typical population remains poorly understood. Method: In a series of 4 experiments that include standardized visual perceptual assessments, autism trait questionnaires, and pupillometry eye tracking tasks, we examine the relationship between focused spatial attention and autism traits. Results: In Experiment 1, observers (N=211) with higher scores on an autism trait questionnaire also perform better on the Figure-Ground (FG) subtest of the Test of Visual Perceptual Skills (TVPS-3). This subtest requires an observer to detect a local form in a global scene. In Experiment 2, we confirm the result from Experiment 1 (N=57) and demonstrate that the relationship is specific to the FG subscale, as no other subtest of the TVPS-3 (i.e. memory, closure, spatial relationships, etc.) is related to autism traits. In Experiment 3, we implement a Navon letter task while recording pupillometry data with an eye tracker (N=34). We find that shifting attention from the global to local part of a stimulus is associated with pupil constriction. In Experiment 4, we implement an eye tracking task that captures reflexive pupil dynamics to changes in luminance (N=42). We show that the amplitude of these reflexive pupil constrictions and dilations are linked to autism traits. Conclusions: These results provide converging evidence that superior performance on tasks that require focused, local form detection is associated with autism traits in the broader population. Furthermore, we demonstrate that pupillary dynamics are relevant to focusing attention in order to detect local forms and quantitative traits associated with the autism phenotype.

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36.3039 **Association between empathic concern and face expression processing in adults with autism spectrum disorder** Fakhri Shafai[1, 2](f.shafai@alumni.ubc.ca), Kimberly Armstrong[3], Grace Iarocci[3], Ipek Oruc[1, 2]; [1]Graduate program in Neuroscience, University of British Columbia, [2]Department of Ophthalmology and Visual Sciences, University of British Columbia, [3]Department of Psychology, Simon Fraser University

Autism Spectrum Disorder (ASD) is a developmental disorder characterized by social-communication difficulties as well as restricted and repetitive behaviour and interests (APA, 2013). One model of ASD considers amygdala dysfunction as a central factor in the disorder (Adolphs et al. 2001) accounting for impaired social perception (e.g. facial expressions) in this population (Walsh et al., 2016; Harms et al., 2010). This hypothesis predicts impairments to be limited to negative emotions. Indeed, multiple studies have reported supporting evidence for this (Poljac et al., 2013; Farran, 2011; Ashwin et al. 2006), though results based on 50 studies on this topic have generally been mixed (Uljarevic et al., 2013). Methodological choices such as use of emotional labeling or expression-matching tasks and assessments of accuracy or reaction times may explain the inconsistency across study results. Previous methods used confound emotion processing with physical stimulus properties and run the risk of ceiling effects, potentially masking group differences. Here we used a two-interval forced choice psychophysical paradigm that allowed us to assess performance across expressions while maintaining the inherent difficulty of the task to measure discrimination thresholds for three expressions (anger, happiness, and sadness) in a group of adults with ASD (n=30) and controls (n=30) matched on IQ. We assessed social competence using the Multidimensional Social Competence Scale (MSCS) (Yager & Iarocci, 2013) and autism symptoms with the Autism Spectrum Quotient (AQ). Participants with ASD were significantly impaired in all expressions tested, including happiness. Our results show a strong association with expression performance and the Empathic Concern (EC) sub-scale and the total social competence score of the MSCS. These findings indicate that social competence is associated with impaired facial emotion processing ability in adults with ASD; affecting positive and negative expressions alike and not specific to negative emotions as postulated in the amygdala theory of ASD.

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36.3040 **Reduced visual metacognitive efficiency in adults with Autism Spectrum Disorder.** Rebecca Lawson[1,2](rebecca.lawson@ucl.ac.uk), Ainslie Johnstone[3], Geraint Rees[1,2]; [1]Wellcome Trust Centre for Neuroimaging, University College London, 12 Queen Square, London, WC1N 3BG, [2]Institute of Cognitive Neuroscience, University College London, 17 Queen Square, London, WC1N 3AR, [3]Oxford Centre for Functional MRI of the Brain (FMRIB), Nuffield Department of Clinical Neurosciences, University of Oxford, Oxford, OX3 9DU

Visual processing is known to be atypical in Autism Spectrum Disorder (ASD), but it is not understood why. A recent and influential Bayesian account of sensory processing in ASD suggested that the interpretation of sensory input is disrupted in individuals with autism (Pellicano and Burr, 2012) and we have hypothesised that perceptual difficulties in ASD may result from a failure of beliefs (estimated confidence) about beliefs (percepts) that is, formally, a failure of metacognition (Friston, Lawson & Frith., 2013). Thus, visual processing itself may not impaired in ASD, but instead the ability to correctly identify the fidelity of ones' own perception. To test this hypothesis we measured perceptual metacognitive efficiency using a non-social visual discrimination task in in adults with and without ASD. Here our primary goal was to dissociate metacognitive sensitivity from general perceptual performance and response biases (Fleming and Lau, 2014). To do so we used a recently developed and validated (Maniscalco and Lau, 2014) decision theoretic measure of metacognitive efficiency to quantify the extent to which confidence ratings can discriminate between correct and incorrect trials in a perceptual (number discrimination) task. Despite equivalent perceptual performance across multiple measures (fixed at 75% accuracy via staircase), adults with ASD showed suboptimal metacognitive efficiency relative to adults without ASD manifest as a reduced correspondence between trial-by-trial fluctuations in confidence judgements with respect to objective perceptual performance. Additional analyses revealed that adults with ASD showed greater overall uncertainty in their responses (e.g. posterior perceptual beliefs) which would offer some initial support for Bayesian accounts that propose "weak priors" in autism. Our results show for the first time that basic perceptual metacognitive ability is compromised in ASD, offering new mechanistic insights into common perceptual symptoms associated with the condition.

Acknowledgement: Wellcome Trust

36.3041 **Action video games improve reading and cross-modal attentional shifting as well as phonological skills in English-speaking children with dyslexia** Andrea Facoetti[1](andreafacoetti@unipd.it), Piergiorgio Trevisan[2], Luca Ronconi[3], Sara Bertoni[1], Susan Colmar[4], Kit Double[4], Chiara Andreola[5], Simone Gori[6], Sandro Franceschini[1]; [1]University of Padua, Italy, [2]University of Udine Italy, [3]University of Trento Italy, [4]University of Sidney Australia, [5]E Medea Scientific Institute Italy, [6]University of Bergamo Italy

Dyslexia is the most common neurodevelopmental disorder characterized by difficulties in learning to read. Action video games (AVG) improve reading efficiency in Italian children with dyslexia, without any direct phonological or orthographic stimulation. However, which mechanism underlying this improvement and the extent to which AVG training would be beneficial in deep English orthography, remain two critical questions. For an efficient reading acquisition children have to integrate written letters with speech sounds, rapidly shifting their attention from visual to auditory modality. Here, we tested reading and phonological skills, audio-visual processing, visual-to-auditory and auditory-to-visual attentional shifting in two matched groups of English-speaking children with dyslexia before and after they played AVG or non action video games. Words recognition and phonological decoding speed increased only playing AVG. Audio-visual processing and visual-to-auditory attentional shifting also ameliorated after AVG training. This unconventional reading remediation program reduced also phonological short-term-memory and phonemes blending deficits. Consequently, the typical auditory-phonological disorders associated to dyslexia also improved playing AVG. Our findings demonstrate that a specific acceleration of audio-visual processing and visual-to-auditory attentional shifting can directly translate into better reading and phonological working memory in English-speaking children with dyslexia.

36.3042 **Investigation of visual aspects of developmental dyslexia in children** Barbara Piotrowska[1](B.Piotrowska@napier.ac.uk), Jennifer Murray [1], Alexandra Willis [1], Jon Kerridge [2]; [1]School of Applied Sciences, Edinburgh Napier University, UK , [2]School of Computing, Edinburgh Napier University, UK

Developmental dyslexia is a disorder characterised by difficulties with reading, despite adequate intelligence and education. Phonological deficits are often indicated as the primary cause of dyslexia. Because a range of lower-level perceptual, attentional, and motor deficits may also be present, it has been argued that phonological deficits are secondary to a visual processing deficit, underpinned by abnormalities in magnocellular or dorsal stream functioning. This proposition mainly emerges from findings which indicate that people with dyslexia show poorer sensitivity to visual stimuli designed to preferentially activate the magnocellular visual stream at the retinal level or the dorsal cortical visual stream. The current research developed a novel "Dot-to-Dot" (DtD) task that may predict children's risk of dyslexia. The current study aimed to elucidate whether magnocellular and dorsal stream functioning are related to DtD task. It further examined whether the performance on the magnocellular and dorsal stream tasks would differ depending on the children's risk of dyslexia. 78 children aged between 6-12 years were tested on a range of cognitive, dyslexia screening and vision tests. The vision tests included contrast sensitivity tests preferentially activating magnocellular and parvocellular pathways. Coherent motion (using an RDK) and coherent form tasks were used to activate the dorsal and ventral streams respectively. The results showed that DtD measures significantly correlated with all visual tasks apart from the coherent motion task. The phonological awareness measure, arguably the best dyslexia predictor, significantly correlated with the visual task tapping into the magnocellular functioning. Furthermore, performance on this task significantly differed between children at medium risk of dyslexia and those at low risk. The current findings seem to provide evidence for the magnocellular deficit in dyslexia, which is consistent with some of the previous literature. However, DtD task was not found to tap specifically into the magnocellular or dorsal stream functioning.

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36.3043 **"When trees overshadow the forest": A peculiar vision of dyslexia** Simone Gori[1,2](simone.gori@unibg.it), Sandro Franceschini[2,3], Sara Bertoni[3], Chiara Andreola[2], Tiziana Gianesini[4], Andrea Facoetti[2,3]; [1]Department of Human and Social Sciences, University of Bergamo, Bergamo 24129, Italy., [2]Child Psychopathology Unit, Scientific Institute "E. Medea", Bosisio Parini, Lecco 23842, Italy., [3]Developmental and Cognitive Neuroscience Lab, Department of General Psychology, University of Padua, Padova 35131, Italy., [4]Neurorehabilitation Unit, Down syndrome association, Verona 37142, Italy.

Individuals usually perceive at first the global visual scene (the "forest"), processed by the right hemisphere, and later the local features (the "trees"), perceived by the left hemisphere. Based on this hierarchical analysis, humans evolved reading ability. However, 10% of people are affected by dyslexia (D) and their reading acquisition is extremely difficult. Learning to read involves multiple linguistic, visual and attentional processes. Differences in perceiving the world might be one of the causes of D. Reversing the global to local world perception has been found to be associated with unusual and extraordinary performance in local features extraction in several neurodevelopmental disorders. Here, we employ a comprehensive approach incorporating all methods to test the causal relationship between D and reverse global to local perception. We tested this causal relationship with five experiments in 336 participants: comparison D with typically reading controls; remediation studies, in which "forest before trees" perception are specifically trained and the subsequent effect on reading improvements is measured, and a prospective-longitudinal approach where "forest before trees" perception is measured in pre-readers and its predictability with future reading development is investigate. Our results reveal that: i) a reverse "forest before trees" perception characterizes children with D; ii) two "forest before trees" perception trainings improve reading skills in children with D, and; iii) pre-reading reverse "forest before trees" perception longitudinally predicts future poor readers. These results demonstrate that learning to read depends also on an efficient right neural network employed for the global analysis of the visual scene.

36.3044 **Learning to read does not affect motion processing in dyslexia** Sung Jun Joo[1,2](sjjoo@uw.edu), Patrick Donnelly[1,2], Jason Yeatman[1,2]; [1]Institute for Learning & Brain Sciences, [2]Department of Speech and Hearing Sciences

Visual sensitivity to motion is correlated with reading skills. Yet, the causal relationship between motion sensitivity and reading skills has been debated for more than thirty years. One hypothesis posits that dyslexia is caused by a deficit in the magnocellular pathway, indicated by deficits in motion processing. An alternative hypothesis maintains that the process of learning to read causes an enhancement in motion sensitivity and, therefore, the motion processing deficit observed in dyslexia is the consequence of a lack of, or poor quality, reading experience. Here we used an intensive reading intervention program to test the causal relationship between learning to read and motion processing. Children (n = 20) received 160 hours of training and practice with phonological and reading skills, and we measured behavioral sensitivity on a motion direction-discrimination task using random dot motion stimuli before (session 1), during (session 2 and 3), and after (Session 4) the intervention to assess how reading intervention affects motion sensitivity. Reading intervention resulted in a substantial increase (~ one grade level) in standardized measures of reading abilities; however, learning to read did not affect motion sensitivity. In each individual, motion sensitivity increased during the first session (before intervention) as children learned to perform the task at threshold, and then sensitivity remained stable over the course of the intervention program. Furthermore, the motion sensitivity deficit did not negatively impact the

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learning process: children with the most severe motion sensitivity deficits showed the same improvement in reading skills as children with typical motion sensitivity. To conclude, our findings call into question the causal relationship between motion sensitivity and dyslexia, and suggest that the correlation between the two might be caused by other common mechanisms, or that motion processing is just one of many factors that contribute to the multifaceted impairments in developmental dyslexia.

Acknowledgement: This work was supported by NSF BCS 1551330 to J.D.Y.

36.3045 **Visual deficits and individual differences in developmental dyslexia** Jason Yeatman[1](jyeatman@uw.edu), Alex White[2], Douglas Strodtman[1], Patrick Donnelly[1], Sung Jun Joo[1]; [1]Institute for Learning & Brain Sciences, University of Washington, [2]Department of Psychology, University of Washington

What is the cause of dyslexia? This question has been the topic of intense debate with competing theories arguing that dyslexia is the result of impaired magnocellular visual sensitivity, crowding, phonological awareness, or various other perceptual and language functions. Here we demonstrate that this is a fundamentally flawed question: the complex and heterogenous phenotype that has been labeled dyslexia can not be reduced to a single core deficit. 59 subjects (25 with dyslexia) participated in multiple sessions including reading and language assessments as well as psychophysical experiments measuring thresholds in tasks targeting the main classes of impairments that have been proposed to cause reading difficulties: (a) motion discrimination using random dot motion stimuli; (b) critical spacing between a target and flankers to correctly identify the target; (c) covert spatial attention using a cued visual search paradigm. We found that multiple psychophysical measures were correlated with reading skills, but no one measure accurately discriminated the dyslexic subjects from the control subjects. For example, some, but not all, of the dyslexics had abnormal motion discrimination thresholds. A subset of dyslexics had heightened visual crowding (elevated critical spacing thresholds), and these dyslexics read significantly faster when text was rendered with increased letter and line spacing. We did not observe a relationship between reading skills and performance on the cued visual search task. Moreover, a subset of the dyslexic subjects had normal thresholds on all psychophysical measures but still performed poorly across reading measures. Analyzing all the measures together, we found that some people with dyslexia cluster into distinct subgroups with specific perceptual impairments. In conclusion, by measuring an array of perceptual, language and reading skills, we demonstrated that there are multiple dimensions to reading difficulties in dyslexia; determining the optimal treatment for an individual will depend on the nature of their specific impairments.

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36.3046 **A critical period for number-related plasticity in the visual cortex of blind individuals** Shipra Kanjlia[1](skanjli1@jhu.edu), Lisa Feigenson[1], Marina Bedny[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

Recent studies suggest that visual cortices are highly functionally flexible, responding not only to non-visual sensory tasks, but also to high-level linguistic and mathematical tasks in congenitally blind individuals (Bedny et al., PNAS, 2011; Kanjlia et al., PNAS, 2016). Specifically, middle occipital gyri are recruited for numerical processing and are sensitive to math difficulty in congenitally blind and not sighted individuals. Is such extreme cortical flexibility unique to a critical period early in development? We asked whether visual cortex plasticity for numerical processing differs across individuals who have been blind from birth and those who became blind as adults. We tested individuals who became blind at 17-years-of-age or later (late blind, LB; n=10; blindness duration: 12-31 years, mean=20.35 years), congenitally blind adults (CB; n=17) and blindfolded sighted controls (S; n=19). Participants underwent fMRI while performing a math task in which they judged whether the value of an unknown variable was the same across two equations (e.g. 7-2=x, 8-3=x). Equations were either single- or double-digit (e.g. 7-2=x vs. 27-12=x) and either algebraically complex or simple (e.g. 7-2=x vs. x-2=7). In a language control task, participants decided if two sentences had the same meaning. Unlike CB individuals, LB individuals do not recruit visual cortices during math calculation more than sighted individuals (whole-brain analysis, $p< 0.05$, cluster-corrected). Furthermore, CB individuals activate right occipital pole (rOP) more than LB individuals during numerical processing ($p< 0.05$, cluster-corrected). Region of interest analyses show that in CB but not LB individuals, rOP is sensitive to digit-number (CB: $F(1,16)=22.78$, $p< 0.001$; LB: $F(1,9)=1.78$, $p=0.22$; group-by-condition interaction: $F(1,25)=4.84$; $p=0.04$) and algebraic-complexity (CB: $F(1,16)=7.53$, $p=0.01$; LB: $F(1,9)=1.26$; $p=0.29$; group-by-condition interaction: $F(1,25)=1.94$; $p=0.18$). Thus, only the visual cortices of individuals who are blind from birth are repurposed for numerical processing, supporting the existence of a critical period for visual cortex plasticity.

Acknowledgement: National Science Foundation, Science of Learning Institute

36.3047 **Differences in Cortical Thickness Reflect Differences in Plasticity of Visual Cortex Between Juvenile and Age-related Macular Degeneration** Matthew Defenderfer[1](mdefende@uab.edu), Mark Greenlee[2], Antony Morland[3], Frans Cornelissen[4], Kristina Visscher[1]; [1]Department of Neurobiology, University of Alabama at Birmingham, [2]Institute for Experimental Psychology, University of Regensburg, Regensburg, Germany, [3]Department of Psychology, University of York, York, United Kingdom, [4]Laboratory of Experimental Ophthalmology, Department of Ophthalmology, University of Groningen, University Medical Center Groningen, Groningen, the Netherlands

Macular degeneration causes loss of central vision while leaving peripheral vision unaffected. People use central vision for many important tasks such as reading and most daily tasks that require attention. Loss of central vision is a drastic change in experience, due to decreased inputs to central vision and the requirement to use peripheral vision for attention-demanding tasks like reading and recognizing faces (Kwon, Nandy, and Tjan, 2013). Central vision loss may lead to changes in cortical properties. This plasticity is thought to be different at different ages and could result in disparate cortical changes depending on when the disease presents. In this experiment, cortical thickness in visual cortex was analyzed in a database of people with juvenile onset macular degeneration (JMD) and adult onset macular degeneration (AMD) and compared between these two groups. A new brain parcellation was used to mark boundaries of V1, V2, and V3 in the left hemisphere of 24 JMD subjects, 33 healthy young controls (HCY), 24 AMD subjects, and 20 healthy older controls (HCO). Each of these areas were divided into separate ROIs based on eccentricity measured using a retinotopic atlas. The data show a clear difference in cortical thickness between participants with central vision loss due to AMD and JMD and their respective controls. ROIs corresponding to central vision show decreased cortical thickness in both AMD and JMD groups. Thinner representations of central vision in both JMD and AMD groups are consistent with decreased activity due to lack of visual input in those regions. Some patterns of cortical thickness differed between AMD and JMD groups, however: AMD had thicker cortex in more peripheral regions corresponding to visual areas of increased use, while the JMD group had similar or thinner cortex. This indicates that the pattern of cortical plasticity differs between JMD and AMD.

Color and Light: Appearance

Sunday, May 21, 2:45 - 6:45 pm
Poster Session, Pavilion

36.4001 **Does color diagnosticity enhance subjective experience of full-color natural scenes?** Eiji Kimura[1], Natsumi Takahashi[1]; [1]Dept. of Psychology, Faculty of Letters, Chiba University

We usually have subjective experience that the entire visual field is in rich color, although color sensitivity is much reduced in the peripheral retina. This “pan-field color” phenomenon (Balas & Sinha, 2007) can be demonstrated by a failure to detect a large achromatized region in either the central or peripheral visual field, with briefly presented scene images. This study investigated the effects of color diagnosticity of scenes on the occurrence of pan-field color. Color diagnosticity refers to the degree to which a scene is associated with specific colors. If pan-field color is mediated by color completion based on color statistics of the scenes, color diagnosticity could enhance its occurrence. We used three window conditions with high and low color-diagnostic scene images subtending 28.6° × 24.3°; Full-color, color-center (only the central 21° region was colored), and gray-center (the central 13° region was achromatized) conditions. The coloring of the scene was also manipulated (normal and complementary colors) to control color-based scene segmentation. The scene image was presented for 70 ms, followed by a mask. The observer’s task was to indicate whether the image had an achromatized region (scotoma). Results showed that observers more frequently missed the scotoma (i.e., pan-field color) in the normal than in the complementary color condition. However, the occurrence of pan-field color was similar with high and low color-diagnostic scenes in both color- and gray-center conditions. Analysis using signal detection theory showed that the scenes in normal color led to a higher sensitivity to the scotoma but also mediated a greater response bias for missing the scotoma. An additional experiment with longer stimulus duration showed that high color diagnosticity provided an advantage for detecting the scotoma, so that reducing the occurrence of pan-field color. Overall, these findings suggested that response bias, rather than color completion, mainly mediates pan-field color.

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36.4002 **Maxwell's spot measurements in changing white light spectra** Marcel Lucassen[1](marcel.lucassen@philips.com), Tobias Borra[1], Jan Souman[1], Luc Schlangen[1]; [1]Philips Lighting Research

The macular pigment covering the fovea maximally absorbs at 460 nm and minimally beyond approximately 540 nm (Bone et al, 1992). Consequently, foveal cones continuously receive less short-wavelength light than cones in surrounding areas, yet in normal circumstances we do not perceive a darker or colored spot in the central visual field. The difference in spectral transmission can be made visible by looking through a dichroic filter to a white surface or by alternately looking at a blue and yellow field. The resulting spot appearance, which fades with time, is called the Maxwell spot. Here, we show that the phenomenon can also be demonstrated by alternately looking at two light fields of similar white appearance, but differing in spectral composition (E1 and E2). When changing from E1 to E2, the color appearance of the spot is complementary to that when changing from E2 to E1. We measured the color appearance of both these spots, using successive haploscopic color matching. The Maxwell spots were generated by exposing the left eye for 6 seconds to E1 and E2 alternated at 0.5 Hz. A synchronized audio signal indicated which of the two Maxwell spots was to be matched. The observers used a computer mouse to navigate through (a*,b*) color space to match the color in the right eye to the perceived color of the Maxwell spot in the left eye, while keeping both eyes at equal (constant) luminance. The spectral distributions E1 and E2 and the color matches were produced by a multi-primary LED light source. Our results indicate that the Maxwell spots are due to differential local chromatic adaptation, i.e. independent sensitivity adjustments of the three cone types. We conclude that even small differences in light appearance may already elicit the Maxwell spot.

36.4003 **Chromatic Induction in a Ganzfeld** Shahram Peyvandi[1](peyvandi@psychology.rutgers.edu), Vebjorn Ekroll[2], Alan Gilchrist [1]; [1]Department of Psychology, Rutgers, The State University of New Jersey, Newark, NJ 07102, USA, [2]Laboratory of Experimental Psychology, University of Leuven (KU Leuven), Belgium

We investigated chromatic induction, which has been attributed to either von Kries adaptation or later-stage post-receptoral adaptation, or a combination of both. Observers' heads were placed inside a large opaque hemisphere, the interior of which consisted of a 3 degree neutral disk surrounded by a chromatic ganzfeld that filled the remainder of the visual field. This apparatus, as opposed to a monitor display, not only allows us to fill the observer's entire visual field, but also to obtain a highly saturated surround of high luminance close to the chromaticity of a spectral color. Both the saturation and luminance of the disk and ganzfeld can be separately adjusted. After one minute of dark adaptation, 20 observers adapted for 45-60 seconds to a colored surround and then adjusted the disk color to make it appear neutral. Conditions included six red surround saturation levels, within a range of 0.736-0.868 in L/(L+M) coordinates, all at a luminance of 90 cd/m2 and four disk values, including two decremental targets (40, 60 cd/m2), one equiluminant, and one incremental target (100 cd/m2). More surround color was needed to null the induced color on a darker target than on a brighter one. This is inconsistent with Kirschmann's third law. However, consistent with Kirschmann's fourth law, the L/(L+M) coordinate of a neutralized target increases non-linearly with that of the surround. This non-linearity, in conflict with Weber cone contrast prediction, becomes more evident at higher surround saturations (L/(L+M) >0.76). According to von Kries adaptation, the chromaticity of all targets which look neutral in a given surround should be the same at all luminance levels. Our data show clear violations of this prediction. Observers found the task difficult, with a majority reporting both red and green close to the neutral setting.

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36.4004 **Yagoto Illusion: illusory colorization on a static achromatic grid pattern.** Yuka Kobayashi[1](kobayashiy333@gmail.com), Kohske Takahashi[1]; [1]Chukyo University

Achromatic patterns appear to be colored in some cases (e.g., Benham's disk, Benham, 1895; Skinner's illusion, Skinner, 1932). Recently we found that an achromatic grid pattern consisting of black borders and white tiles, thus a pattern like a negative-positive reversal of Hermann Grid illusion, induces illusory colorization ("Yagoto Illusion," awarded in the 8th Illusion Contest in Japan). We can observe that white squares surrounded by black borders were colored with various vague colors. Since Yagoto Illusion does not require rotation of a figure (Benham's disk) or inspection through a pinhole (Skinner's illusion), the colorization may be mediated by novel mechanisms of color vision. In the present study, we conducted two experiments to examine the characteristics of Yagoto Illusion. In these experiments, we presented two grid patterns side-by-side, one of which was a chromatic grid pattern (black borders and vaguely colored whitish tiles) as a sample and the other was an achromatic grid pattern (blackish borders and whitish tiles) as a test. Participants reported subjective strength of colorization of the test stimulus in comparison to the sample stimulus. In Experiment 1, we manipulated the size of tiles and the width of border, and found that the smaller tiles as well as the thinner borders resulted in the stronger illusory colorization. In Experiment 2, we manipulated the brightness of the achromatic tiles and borders. The results demonstrated that the darker borders led to the stronger colorization. Furthermore, contrarily to the previous reports of illusory colorization wherein the higher black-white contrast induced the stronger colorization (e.g., Packer & Williams, 2003), the stronger colorization was observed for the darker tiles (i.e., weaker contrast) in Yagoto Illusion. Thus, some types of illusory colorization would be more effective for the low contrast stimulus.

36.4005 **Edge integration and image segmentation in lightness and color** Michael Rudd[1](mrudd@uw.edu); [1]Department of Physiology and Biophysics, University of Washington

Previous work has demonstrated that lightness in disk-annulus displays can be explained by a computational model based on the principle of edge integration (Rudd, Front. Hum. Neurosci., 2014). The disk lightness depends not just on the contrast, or luminance ratio, of the disk with respect to its immediate surround, but instead on a weighted sum of luminance steps (in log units) computed along a path from the background, through annulus, to the disk. The idea of summing steps in log luminance to compute lightness makes ecological sense as a means of relating the disk luminance to the background luminance for the purpose of constructing a global reflectance map, starting from information about local changes in luminance that might be encoded by early visual neurons (Rudd, 2014; J. Electron. Imaging, submitted). Edge integration theory explains disk-annulus lightness matching results with great precision, but can the theory generalize to explain surface lightness and color appearance in other contexts? Here I shown how it can account for assimilation in the classic Helson display, and in a new display--the Nebraska election map--in which the yellow color of hatched diagonal lines draw within an otherwise red region bleed into the red. I also present displays that I have constructed by modifying White's display. In these displays, edge integration operates within regions that are first visually segmented according to principles of perceptual organization. The phenomenology of my modified White's displays supports the conclusion that steps in log luminance sum to compute target lightness only within the segmented region to which the target perceptually belongs, suggesting a role of perceptual grouping or scission in depth in White's effect. My new results cannot be explained either by low-level normalized filter models, such as ODOG, or by an edge integration theory that ignores the role of image segmentation.

36.4006 **Evidence for at least four colour appearance mechanisms** Sophie Wuerger[1](s.m.wuerger@liverpool.ac.uk), Kaida Xiao[2], Tushar Chauhan[3]; [1]University of Liverpool, [2]University of Leeds, [3]University of Toulouse

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Colour vision starts in the retina where light is absorbed in three different cone classes, sensitive to long-, medium-, and short-wavelength light. The cone signals then feed into three post-receptoral channels, a luminance channel and two cone-opponent chromatic -channels. Behavioural experiments have shown that these two cone-opponent chromatic channels do not correspond to perceptually salient colour mechanisms (unique red, green, yellow, blue). The red-green mechanism, which is at equilibrium for unique yellow and blue, is approximately linear in cone space. On the other hand, the yellow-blue mechanism, which is at equilibrium for unique red and unique green, is known to be non-linear. If unique yellow and unique blue are indeed generated by a single red-green mechanism, then one would predict that the individual differences in the red and green settings are correlated; similarly for unique red and green. We tested this hypothesis by analysing the unique hue settings at different saturation and lightness levels for a large sample of observers (n=185). Our results show that the individual differences in the opponent pairs (red-green; yellow-blue) are not correlated. We have confirmed this result by analysing the data in different colour spaces (cone space, u'v'). This is inconsistent with the hypothesis that the unique hues are generated by two perceptually opponent mechanisms. We conclude that there are at least four unipolar colour appearance mechanisms.

36.4007 **Resolution of interocular-switch rivalry by neurons following orientation-color feature integration** Emily Slezak[1,2](easlezak@uchicago.edu), Steven Shevell[1,2,3]; [1]Department of Psychology, University of Chicago, [2]Institute for Mind and Biology, University of Chicago, [3]Department of Ophthalmology & Visual Science, University of Chicago

Steadily presented, binocularly rivalrous dichoptic stimuli with multiple features can induce feature binding errors in the resulting percept (Hong & Shevell, 2009). This is consistent with rivalrous colors and forms being resolved separately (Sterling, 1901). However, many binocular V2 neurons are tuned to a combination of chromaticity and orientation (Gegenfurtner, 2003). The present study used dichoptic grating stimuli that could differ in both orientation and chromaticity to determine if the percept is resolved in binocular neurons driven by individual features or conjunctions of features. METHODS Three observers viewed dichoptic equiluminant chromatic square-wave gratings, swapped between the eyes at 3.75 Hz (interocular-switch rivalry). Two conditions were tested: rivalrous gratings differed in [1] only orientation (say, green vertical and green horizontal) or [2] both orientation and chromaticity (green vertical and red horizontal). If the resolution of ambiguity occurs in binocular neurons driven by an individual feature, such as orientation or color, condition [2] allows for misbound percepts (red vertical). If the percept is resolved by neurons tuned for feature conjunctions, misbound percepts should not be seen. Observers reported their percepts of the dichoptic stimuli by pressing buttons on a gamepad. RESULTS Interocular-switch rivalry in condition [1] did not evoke binocular rivalry; instead, the percept was the superimposition of the stimuli (a plaid). Interocular-switch rivalry, however, does not eliminate suppression: with the simple addition of the second chromaticity in condition [2], observers no longer perceived a plaid. Instead, with joint orientation and color rivalry in [2] the percept alternated between the two stimuli. A control experiment eliminated the possibility that this difference in [2] was due to a luminance artifact. All observers perceived only the orientation-color combinations presented in the stimuli, indicating that the resolution of ambiguity caused by interocular-switch rivalry occurs in binocular neurons following feature integration.

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36.4008 **Perceptual compensation in anomalous trichromats?** John Vanston[1](jvanston1206@gmail.com), Katherine Tregillus[1], Michael Crognale[1]; [1]Psychology Department, College of Liberal Arts, University of Nevada, Reno

Anomalous trichromacy is the most common form of color vision deficiency (CVD), wherein one cone class expresses an abnormal photopigment. In anomalous trichromats, this causes decreased discrimination and sensitivity in the red-green dimension of color vision. However, the visual system can recalibrate its outputs based on its inputs through neural adaptation. Thus, long-term adaptation might compensate for decreased red-green inputs. A recent study used unique hue judgments to evaluate the scaling of perceptual color spaces of anomalous trichromats and color normal subjects (Boehm et al., 2014). The CVD subjects in their study had dimensional scaling more similar to color normals than their discrimination thresholds predicted, suggesting a compensatory mechanism. The current study expands upon this research by investigating whether this compensation is present in perceptual contrast matches between stimuli that vary along chromatic and achromatic axes in a cone-opponent space. Subjects were screened for color vision deficiency using pseudoisochromatic plate tests. Those identified as CVD were further classified using Rayleigh matches on a Nagel Anomaloscope. For all subjects, discrimination thresholds, which should be unaffected by cortical compensation mechanisms, were measured using the Cambridge Colour Test. A suprathreshold matching task was used to measure perceptual scaling across axes in a modified DKL space. Test stimuli in this task were 10° gabors modulated along the isoluminant L-M and S-(L+M). Using a staircase procedure, subjects matched the contrast of chromatic gratings to a standard achromatic comparison grating. Preliminary data show a high correlation between discrimination thresholds measured by CCT and suprathreshold contrast matches between L-M stimuli and reference achromatic stimuli, for both color normal subjects and anomalous trichromats. That is, suprathreshold matches are well predicted by threshold measurements. This suggests that the perceptual compensation measured using unique hue judgments may not manifest as changes in scaling of suprathreshold contrast matches.

36.4009 **Chromatic Induction and the Flash Lag Effect** Andrew Coia[1](acoia@uchicago.edu), Steven Shevell[1,2]; [1]Institute For Mind and Biology, University of Chicago, [2]Departments of Psychology and Ophthalmology & Visual Science, University of Chicago

The flash lag effect demonstrates that a flashed object is perceived to lag behind a moving one even when they are identical at the moment of the flash. Anstis (2007), using a motion illusion, showed that the flash lag depends on physical rather than perceived motion. A variant of the flash lag effect occurs with color: the color of a flashed object appears to lag behind the color of another object continuously changing in chromaticity. The current study tested whether color flash lag judgments are based on perceived color or physical chromaticity. METHODS: Chromatic induction was employed to make a test ring, which appeared red on a neutral grey surround, appear orange when surrounded by one chromatic pattern or pink when surrounded by another pattern (patterned surrounds after Monnier and Shevell, 2003). Matching experiments compared test rings within patterned surrounds (induction) to rings within a uniform neutral surround (no induction). Observers adjusted the chromaticity of the flashed ring to match the color of the changing ring. The changing-ring's chromaticity could go from either orange→red→pink, or pink→red→orange. RESULTS: Initially, both test rings were on uniform neutral surrounds. These baseline measurements confirmed the color flash lag effect, and were compared to conditions with either the changing or flashed ring within a patterned surround. When only the changing ring had a patterned surround, observers shifted the color of the flashed ring to account for chromatic induction from the surround. Similarly, when only the flashed ring had a patterned surround, observers' matches also were shifted by the surround. CONCLUSION: The flash lag effect for color is based on the color perceived, not the physical chromaticity of the stimulus. This differs from the motion flash-lag effect (Anstis, 2007), indicating that flash lags for motion and for color are mediated by different neural mechanisms.

36.4010 **Effect of Multi-notch filter on Color Arrangement Test Performance in Color Normal and Color Deficient Humans** Julia Kitchens[1](juliakitchens@gmail.com), Patricia Cisarik[1]; [1]Southern College of Optometry

Color mis-identification can impair safety and job performance. Optical filters can help color deficients discriminate colors within a scene. A "multinotch" filter (EF) is available that increases separation between medium and long wavelength spectral sensitivity curves to improve color perception by anomalous trichromats. Our purpose was to investigate changes in color perception induced by the EF in color normal (CN) and color deficient (CD) humans. Farnsworth 100 hue test was performed on one eye of 50 CNs and 12 CDs with the EF and with a neutral density (ND) filter of similar total transmission. Total error scores and error scores for each of four distinguished boxes of color chips were calculated. Correlated samples t-test was used to compare error scores for both filter conditions. For CNs, a difference in mean error score was significant for Box 22-42 ($p < 0.0001$) and for Box 43-63 ($p = 0.0002$), with mean error score higher with EF. For CDs, a difference in mean error score was significant for Box 22-42 (p =

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0.006), with mean score higher with EF; a difference in mean error score was also significant for Box 43-63 (p = .004), with mean score higher with ND. Total mean error score for CNs was higher with the EF (14.63) vs. ND (11.65) (p = .0001). Total mean score for CDs was not significantly different between EF (49.6) vs. ND (46.9) (p = 0.5). The EF significantly lowered mean error score for Box 43-63, but significantly elevated mean error score for Box 22-42 in our CDs. Total error score for CDs was not significantly altered compared to ND. These filters may be useful for improving color discrimination in a segment of the spectrum, but do not create more normal overall color perception as measured by the Farnsworth 100 hue test.

Acknowledgement: Southern College of Optometry

36.4011 **Motion-induced Appearance Shift Depending on Orientation** Sang Wook Hong[1,2](shong6@fau.edu), Min-Suk Kang[3]; [1]Department of Psychology, Florida Atlantic University, [2]Center for Complex Systems and Brain Sciences, Florida Atlantic University, [3]Department of Psychology, Sungkyunkwan University

Recently we show that motion signal from neighboring objects alters brightness and color of both the moving and the stationary objects, and consequently the stationary objects appear different from the moving ones although they are physically identical (Hong & Kang, 2013, 2016). In the current study, we investigated whether this motion-induced appearance shift is affected by spatial structure of the stationary and moving objects. Using memory-based choice task, we measured the appearance of a stationary, vertical bar presented 2-deg away from the central fixation. In the same orientation condition, another vertical bar was orbiting around the stationary bar. In different orientation condition, a horizontal bar was orbiting around the stationary vertical bar. We found that the magnitude of brightness shift was significantly reduced when orientations of stationary and moving bars were perpendicular to each other compared to when orientations of them were identical (both vertical). However, the orientations of stationary and moving bars did not significantly modulate the magnitude of color appearance shift due to contextual motion. We discussed underlying mechanisms mediating this discrepancy between brightness and color appearance shift associated with stimulus motion

36.4012 **The Wilson-Cowan model describes Contrast Response and Subjective Distortion** Marcelo Bertalmío[1](marcelo.bertalmio@upf.edu), Praveen Cyriac[1], Thomas Batard[1], Marina Martinez-Garcia[2], Jesús Malo[2]; [1]Universitat Pompeu Fabra, Barcelona, Spain, [2]Universitat de València, Valencia, Spain

The Wilson-Cowan equations were originally proposed to describe the low-level dynamics of neural populations (Wilson&Cowan 1972). These equations have been extensively used in modelling the oscillations of cortical activity (Cowan et al. 2016). However, due to their low-level nature, very few works have attempted connections to higher level psychophysics (Herzog et al. 2003, Hermens et al. 2005) and, to the best of our knowledge, they have not been used to predict contrast response curves or subjective image quality. Interestingly (Bertalmío&Cowan 2009) showed that Wilson-Cowan models may lead to (high level) color constancy. Moreover, these models may have positive statistical effects similarly to Divisive Normalization, which is the canonical choice to understand contrast response (Watson&Solomon 1997, Carandini&Heeger 2012): while Divisive Normalization reduces redundancy due to predictive coding (Malo&Laparra 2010), Wilson-Cowan leads to local histogram equalization (Bertalmío 2014), another route to increase channel capacity. Here we show that the functional (statistical) similarities between Wilson-Cowan and Divisive Normalization actually hold and may be extended to contrast perception. Specifically, first we fitted the Wilson-Cowan model using a procedure reported for Divisive Normalization: following (Watson&Malo 2002, Laparra&Malo 2010), we maximized the correlation with human opinion in quality assessment. Secondly, we used the resulting model to predict the visibility of textured patterns on top of backgrounds of different frequencies and contrasts as in classical masking experiments. Finally, we checked the redundancy reduction of Wilson-Cowan and Divisive Normalization in the same way (as in Malo&Laparra 2010). Results show that (1) Wilson-Cowan is as good as Divisive Normalization in reproducing image distortion psychophysics, (2) Wilson-Cowan dynamics induces saturating responses that attenuate with the contrast of the background, particularly when the background resembles the test; and (3) mutual information between V1-like responses after the Wilson-Cowan interaction decreases similarly as in Divisive Normalization.

COLOR AND LIGHT: OTHER

Sunday, May 21, 2:45 - 6:45 pm
Poster Session, Pavilion

36.4013 **How redundant are luminance and chrominance information in natural scenes?** Camille Breuil[1](camille.breuil@gipsa-lab.fr), Simon Barthelmé[1], Nathalie Guyader[1]; [1]GIPSA Laboratory, CNRS, Grenoble, France

Color vision is an impressive ability of the human visual system. Three different types of cones in the retina, and then three postreceptoral cone-opponent mechanisms enable us to extract both luminance and chromatic information from our environment. Theories of efficient coding argue that the visual system evolved this way to optimally process natural scenes. Therefore, the study of statistical properties of natural images has great potential value to expand our understanding of visual perception. From that perspective, a central question is to characterize the role of chromatic information: in natural scenes, what information can be extracted from chromatic channels that is not already present in luminance? The literature on this point is contradictory. On the one hand, several studies have investigated the joint distribution of luminance and chrominance, finding that luminance and chromatic edges are not independent (Fine et al. 2003) and that most edges are defined by luminance contrast with color information being redundant (Zhou & Mel 2008). On the other hand, Hansen and Gegenfurtner (2009) showed using mutual information that luminance and chromatic edges constitute relatively independent sources of information and that their independence increases along successive stages of visual processing. Here we improve and extend their analysis, using ~1000 images taken from the McGill calibrated color image database (Olmos & Kingdom, 2004) to quantify the redundancy of luminance and chrominance information in each image individually. While we replicate the main findings of Hansen and Gegenfurtner (2009), we also find that the estimated amount of mutual information depends on how the images are processed. The most critical step is divisive normalization, a late stage in the processing pipeline. How redundant chrominance and luminance are, may thus depend on the precise definition of these two quantities, explaining some inconsistencies in the literature.

Acknowledgement: LabEx PERSYVAL-Lab (ANR-11-LABX-0025-01)

36.4014 **Influences of sunrise and morning light on visual behavior of four sympatric New World primates (Ateles, Callicebus, Lagothrix, and Pithecia)** Max Snodderly[1,2](max.snodderly@austin.utexas.edu), Kelsey Ellis[2,3], Sarina Lieberman[1,2], Andrés Link[2,4], Eduardo Fernandez-Duque[5], Sara Alvarez[6], Laura Abondano[2,3], Anthony Di Fiore[2,3]; [1]Department of Neuroscience, University of Texas at Austin, [2]Fundación Proyecto Primates, Bogota, [3]Department of Anthropology, University of Texas at Austin, [4]Departamento de Ciencias Biológicas y Administración, Universidad de Los Andes, Bogota, [5]Department of Anthropology, Yale University, [6]Wildlife Department, Universidad Regional Amazónica IKIAM, Ecuador

Among New World primates, only one genus out of 18 is known to have routine trichromatic color vision like humans. All other species investigated to date have diverse color vision genotypes that suggest potential diversity in their visual ecology. Some evidence indicates that specific color vision phenotypes, particularly dichromats, are more successful when foraging in dim light or foraging for cryptic prey. Using light spectra measured during the transition from darkness to daylight, and behavioral data collected during ongoing studies, we analyzed the timing of the earliest activities requiring vision. For four sympatric primates at the Tiputini Biodiversity Station in Amazonian Ecuador we found no evidence of activity occurring before the onset of nautical twilight (~48 min before sunrise). Observers on the ground frequently thought that monkeys began their morning activity in darkness, but measures of the quantum flux between 400 and 700 nm showed that only 1-2% of the light at canopy level reaches the ground, so the light available to the animals is ~2 log units higher. The larger monkeys (Ateles and Lagothrix), whose diets include a high proportion of ripe fruit, left their sleeping trees and began to move through the canopy earlier than

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the smaller monkeys whose diets are more diverse (Callicebus) or include more cryptic, unripe fruits (Pithecia). Although human observers at canopy level were able to distinguish colors and fine detail at 21-23 min before sunrise, most of the monkeys waited until after sunrise to begin feeding. For the larger monkeys, 80-90% of the feeding bouts occurred after sunrise, and for the smaller monkeys, 100% of the feeding bouts occurred after sunrise. Thus, it appears that the monkeys wait for good viewing conditions before feeding, and they are not exploiting the dim light of twilight where dichromacy might confer some advantages.

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36.4015 **Circadian and fatigue effects on the dynamics of the pupillary light reflex** Terence Tyson[1,2](terence.l.tyson@nasa.gov), Erin Flynn-Evans[1], Leland Stone[1]; [1]Human Systems Integration Division, NASA Ames Research Center, [2]Department of Industrial and Systems Engineering, Charles W. Davidson College of Engineering, San Jose State University

The pupillary light reflex (PLR) is known to be driven by the photo-entrainment of intrinsically-photosensitive retinal ganglion cells. These ganglion cells are known to have retino-hypothalamic projections to the suprachiasmatic nuclei (SCN), which regulates circadian rhythms, and bilateral retinal projections to the pretectal area, which mediates the PLR (Dacey et al., 2005; Hattar et al., 2002, 2006). The magnitude of the PLR has previously been shown to show circadian variation (Münch et al., 2012). In this study, we used a constant routine protocol (Mills et al., 1978) to examine circadian and fatigue effects on the dynamics of the PLR. We characterized the PLR (pupil size as a function of time) in response to a square-wave change in the luminance of a white display background, at ten different times over a single circadian cycle. Twelve subjects participated in three "daytime" baseline runs followed by 7 "nighttime" runs each separated by an hour (17 – 23 hours after awakening). The constriction and dilation phases of the PLR waveform were fit separately with a single exponential model (Longtin & Milton, 1988; Milton & Longtin, 1990) with time constants estimated using a least-squares method. The dilation time constant exhibited a distinct sinusoidal modulation across the circadian cycle and, after 23 hours of wakefulness, decreased on average by 82 ms (paired t-test, $p < 0.05$) relative to baseline (mean: 543 ms). The constriction time constant however, did not show an overall decrease with increased wakefulness. We conclude that the dynamics of the PLR show circadian variation and that, in addition, the briskness of the dilation response to a step-decrease in luminance shows a homeostatic enhancement with increased wakefulness.

36.4016 **I spy with my little eye: A simple behavioral assay to test color perception in animal virtual reality setups** Alexander Knorr[1], Céline Gravot[2,3,4], Hans Straka[2,3,4], Stefan Glasauer[1,3,4]; [1]Center for Sensorimotor Research, Department of Neurology, University Hospital Großhadern, [2]Division of Neurobiology, Department Biology II, Ludwig-Maximilians-Universität München, [3]Graduate School of Systemic Neurosciences, Department Biology II, Ludwig-Maximilians-Universität München, [4]RTG2175, Department Biology II, Ludwig-Maximilians-Universität München

Virtual reality has become an increasingly popular and powerful tool to study behavior and perception in humans and – more recently – also in animals. Driven by the advances in computer animation technology, virtual realities (VR) can now closely mimic natural scenes. However, little is known about how animals (whose photoreceptors differ from those of humans) perceive colors that are presented on RGB digital screens. In this study, we present a simple behavioral assay to test color perception in an animal VR setup and demonstrate results from experiments employing semi-intact preparations of Xenopus laevis tadpoles at mid-larval stages. The optokinetic reflex (OKR) is a visual motion driven gaze-stabilizing motor reaction and appropriately elicited by an internal representation of the visual surround's movement. Online eye tracking permits a measurement of the OKR in response to different visual scenes in a VR setup. Optokinetic stimuli were presented at a constant velocity (±10°/s, 0.2 Hz) using black/color striped patterns in any of the three component colors (red, green and blue). By varying the intensity of the colored stripes, we obtained response amplitude curves for each color. The intensities required to obtain an optokinetic response above a specific threshold level were determined by the relative sensitivity to an individual RGB color and was used to estimate the relative spectral sensitivity of Xenopus tadpoles. Systematic employment of this technique demonstrated that the relative sensitivity (cR,G,B) to the component colors of the display were $cR = 0.275 \pm 0.032$ for red, $cG = 0.585 \pm 0.028$ for green and $cB = 0.140 \pm 0.017$ for blue in Xenopus laevis tadpoles. This relatively simple method can thus be extended to other species using other suitable visuomotor transformations as behavioral readout to validate color presentation in virtual reality setups used for animal experiments.

36.4017 **Why do LCD screens appear to glow?** Khushbu Patel[1,2](khushbup@my.yorku.ca), Leonard Palatnic[1,2], Richard Murray[1,2]; [1]Department of Psychology, York University, [2]Centre for Vision Research, York University

High-resolution LCD screens can depict realistic scenes, but even under restricted viewing conditions (e.g., monocular, stationary) we can usually tell that the surfaces and objects shown are not real. One reason may be that we can tell that the screen emits light instead of simply reflecting incident light. Here we investigated what cues allow observers to determine that a small patch of an LCD screen is light-emitting rather than reflective. We cut a 3 x 3 grid of nine 3.2 cm square apertures in each of 27 black cardboard panels. Behind eight randomly selected apertures on each board we attached patches of gray and off-gray (e.g., beige) paper; we left the ninth aperture empty. The paper patches were picked randomly from twelve samples. On each trial we put a board in front of a light-emitting LCD screen, and the observer judged which aperture contained the screen. In the luminance-match and colour-match conditions, the screen showed a gray region whose luminance or colour (i.e., CIE XYZ coordinates), respectively, were matched to a randomly chosen paper patch. In the texture-match condition the screen showed a colour-calibrated photograph of a randomly chosen paper patch. The three 108-trial conditions were randomly interleaved. All observers (n=5) were well above chance performance in the luminance-match condition (95% correct), two were above chance in the color-match condition (16% correct), and three were above chance in the texture-match condition (30% correct). We conclude that color is an important cue for glow detection, but not the only relevant cue. Further work will explore the role of cast shadows and texture-based lighting direction cues in making LCD screens discriminable from reflective surfaces.

36.4018 **Abnormal Retinal Functioning in Schizophrenia and its Relationship to Performance on Low- and Mid-Level Visual Processing Tasks** Docia Demmin[1](dldemmin@gmail.com), Matthew Rochè[1], Quentin Davis[2], Aaron Seitz[3], Aaina Menon[1], Steven Silverstein[1]; [1]Rutgers, The State University of New Jersey, Piscataway, NJ, [2]LKC Technologies, Gaithersburg, MD, [3]Department of Psychology, University of California - Riverside, Riverside CA

The retina is part of the CNS and provides a window into brain structure and function that has been useful in examining schizophrenia and other neuropsychiatric disorders. Several prior flash electroretinogram (fERG) studies have demonstrated that ERG amplitudes are reduced in schizophrenia, and that latencies are prolonged. In this study we used fERG to determine which retinal cell types (photoreceptor, bipolar, ganglion) demonstrate impaired signaling, and under which conditions (scotopic vs. photopic) the impairments are most pronounced. In addition, we examined relationships between abnormal ERG values and performance on measures of visual acuity, contrast sensitivity, and contour integration. Data were collected on 25 schizophrenia patients and 25 healthy controls. The primary variables of interest were a-wave activity (reflecting photoreceptor response), b-wave activity (reflecting primarily bipolar cell activity) and the photopic negative response (PhNR) (reflecting ganglion cell activity). On light-adapted tests, schizophrenia patients demonstrated significantly weaker photoreceptor response when a flash was presented against an unlit background, and during a steady-state flicker test. On dark-adapted tests, the rate of photoreceptor response gain per unit of intensity increase was significantly weaker for patients than controls. In dark-adapted conditions, patients also demonstrated weaker signaling of bipolar cells. The schizophrenia group was characterized by a marginally weaker PhNR. ERG latencies were generally normal in all tests. Correlations between ERG indices and other test scores were generally not significant and were not consistent across ERG trials. Overall, these data suggest that both reduced signaling of photoreceptor and bipolar cells, as well as attenuated response gain, are associated with schizophrenia. Moreover, both rod and cone responses appear to be affected. However, weakened retinal signaling is not consistently related to visual task performance, perhaps due, in part, to compensatory LGN or cortical gain control mechanisms.

36.4019 **How Traumatic Brain Injury Affects the Human Retina**

Christopher Tyler[1](cwt@ski.org), Lora Likova[1]; [1]Smith-Kettlewell Eye Research Institute

Introduction. Spectral analysis of electroretinographic (ERG) responses provides a non-invasive probe for the functioning of a broad range of receptor and inner retinal mechanisms the in human eye. We investigated the visual and ERG characteristics in a sample of sufferers of traumatic brain injury (TBI) with and without hypersensiivity to light (photalgia). Methods. We recorded light-adapted electroretinograms (ERG) from facial electrodes. High-quality ERG responses for full-field stimulation as a function of wavelength and intensity were obtainable for whole-field chromatic R (610 nm), G (540 nm), B (480 nm) and W (R + G + B) stimulation with 2.5 Hz square-wave modulation (200 ms on/ 200 ms off) at a maximum intensity of 265 cd/m2 (W). Signals were recorded from a population of individuals with varying degrees of photalgia due to mild traumatic brain injury, and controls. Photalgic participants used a staircase procedure to set each stimulus to the highest tolerable intensity. Results. Light-adapted ERGs in controls exhibited similar properties to dark-adapted ERGs, with the a-wave peak at about 20 ms, the b-wave peak at about ~40 ms and the photopic negative response (PhNR) at about 80 ms, consistent with an origin in the cone pathways. The 660 nm condition reveals a striking second peak in the b-wave known as the x-wave, which may derive from rod responses but seems to be masked by the PhNR at other wavelengths. These functional properties were significantly altered across the TBI population, with marked attenuation and delayed b-wave peaks and loss of the PhNR after taking into account the requisite intensity reductions, especially in those with photalgia. These abnormal features could be interpreted as profound reductions in the cone signal contributions to the ERG. Conclusion. The ERG changes in the TBI patients potentially provide the first objective biomarker for retinal effects of TBI.

Acknowledgement: CDMRP 130266

ATTENTION: EXOGENOUS AND ENDOGENOUS

Sunday, May 21, 2:45 - 6:45 pm
Poster Session, Pavilion

36.4020 **The effect of cue frequency on bottom-up attention**

Yosun Yoon[1](yosunyoon@gmail.com), Shin Young Jung[2], Eunhee Bae[2], Suk Won Han[2]; [1]Department of Psychology, Chungbuk National University, [2]Department of Psychology, Chungnam National University

A salient, but task-irrelevant cue captures attention in an automatic fashion. While this bottom-up attentional capture has been claimed automatic, growing evidence shows that such attentional effect is susceptible to top-down factors, such as task settings or trial contexts. In the present study, we provide further evidence that task setting affects the effect of bottom-up attention. A novel manipulation of the present study is that the frequency of cue presentation varied. Notably, in many previous cuing studies, a salient cue stimulus was presented in nearly all trials. We suspected that this frequent cue presentation would influence participants' task strategy or evoke some demand characteristics, modulating the cuing effect. To test this possibility, we had two groups of participants perform a task of identifying a single letter. The target letter was preceded by a salient, spatial cue, whose location matched (valid) or did not match (invalid) the target location. There were also neutral trials in which all the potential target locations were cued. The probability that the cue and target location match was chance, rendering the cue non-informative of the target location. Importantly, for a group, the cue (valid, neutral, or invalid) was presented in 75% of all the trials (cue-frequent), whereas for the other, only the 25% of the trials included the cue stimulus (cue-infrequent). The result showed that the cuing effect was significantly larger for the cue-infrequent group, as revealed by a significant interaction between cue type and cue frequency, $p < .01$. In a second experiment, the target was accompanied by distractors. We also found a significant interaction between cue type and cue frequency, $p < .01$. These challenge the claim that the nature of attention mediated by salient, task-irrelevant cues is strictly automatic.

36.4021 **The spatial distribution of exogenous feature based attention**

Ian Donovan[1](ian.donovan@nyu.edu), Ying Zhou[1], Marisa Carrasco[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Introduction. Only two studies have explicitly manipulated and shown the effect of exogenous feature-based attention (FBA; Lin, Hubert-Wallander, Murray, & Boynton, 2011; Qian & Liu, 2015), both reporting effects on reaction time (RT) that emerge faster than endogenous FBA. Endogenous FBA is known to spread across space but for exogenous FBA, its distribution across space and effect on accuracy are unknown. Here, we investigated the spatial distribution of exogenous FBA. Methods. Participants discriminated the orientation (vertical or horizontal) of one colored ellipse within an array of five colored circles. Each stimulus was a different color, and could appear at any of eight isoeccentric locations, at all cardinal (horizontal and vertical) and intercardinal locations. An uninformative pre-cue was presented at the center of the screen, the color of which matched either the target (valid) or one of the distractors (invalid). Three ISIs between the cue and the stimulus display were used in separate blocks – 100, 200, and 300 ms. Results. There was a significant interaction between ISI, Feature-Cue Validity, and Location. For locations along the cardinal axes (horizontal and vertical), accuracy was higher for valid trials compared to invalid trials. This effect emerged only for the short, 100ms ISI. No differences in accuracy were observed between valid and invalid trials for intercardinal locations. Further, there was no significant effect of RT, indicating no speed-accuracy tradeoff. Conclusions. Our results suggest that exogenous FBA is not evenly distributed across space. Specifically, exogenous FBA facilitates performance as fast as 100ms after a cue appears, and this effect is constrained by the location of the stimulus, emerging only along the cardinal axes, and not at the intercardinal locations. This contrasts with endogenous FBA, which spreads across space and takes about 500 ms to be deployed.

36.4022 **Modulation of inhibition as a function of distractor cue validity**

Dipanjana Das[1](ddas4425@gmail.com), Barry Giesbrecht[1]; [1]UC Santa Barbara

Prior knowledge of the location of an upcoming target results in faster and more accurate identification of the target (Posner, 1980). There is some evidence that prior knowledge of distractor locations can also aid target identification. Munneke, Van der Stigchel and Theeweus (2008) report reduced distractor compatibility on trials when the location of the distractor was cued compared to un-cued. Noonan et al. (2016) reported that cueing the location of an upcoming distractor is effective in inhibiting the distractor only if the cued location was blocked rather than updated on a trial-by trial basis. Here we further test the nature of distractor inhibition by manipulating the validity of cues that signal the most likely location of upcoming distractors. If inhibition is a top-down mechanism, then there should be reduced distractor interference on validly cued compared to invalidly cued or neutral (un-cued) trials. We tested this prediction using a spatially-distributed flanker task in which the location of the distractor was cued validly (80 percent), invalidly (20 percent) or neutrally (10 percent). Invalid cues pointed either to a location in which neither target nor distractor appeared (Invalid-I) or to the location of the upcoming target (Invalid-II). Participants reported the orientation of a target sinusoid grating while ignoring a distractor sinusoid grating, which could be compatible or incompatible to the target. Preliminary analyses (n=15) of accuracy reveal a significant flanker effect in neutral trials ($t(14)=2.161$, $p=.049$) compared to no flanker effect in validly cued trials ($t(14)=.602$, $p=.557$), suggesting flanker reduction for valid compared to neutral trials. Further, a significant flanker effect on invalid trials in which the target appeared at the distractor-cued location ($t(14)=2.271$, $p=0.039$), suggests inhibition of that location. These findings point to an adaptive, top-down mechanism of distractor inhibition.

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36.4023 **Modulation of alpha power reveals interaction between top-down and bottom-up effects during visual selective attention**

Lia Bonacci[1](liab@bu.edu), Scott Bressler[1], Barbara Shinn-Cunningham[1]; [1]Auditory Neuroscience Lab, Boston University, Boston, MA USA

Interaction with the outside world is guided by the ability to switch and maintain attention. While top-down attention drives object selection, bottom-up influences can interfere, causing an individual to switch their focus to another target. Top-down modulation of alpha power (8-14 Hz) has been reported in cued attention paradigms, but has rarely been examined during tasks involving dynamic stimuli. In this study, the neural representation of top-down and bottom-up interactions was explored during three visual selective attention tasks. All three tasks involved two competing sequences of flashing arrows to the left and right of a central fixation point. In each sequence, arrow orientations changed over time, resulting in different trajectories. Subjects were cued to attend either the left or right target sequence and report its trajectory. Passive trials, requiring no action, were included as a control. Tasks had zero, one, or six flashing distractor arrows at locations separate from the two target sequences. All arrow timings were staggered, allowing association of event-related neural activity with individual arrow onsets. In order to obtain alpha power measurements, EEG was recorded simultaneously in 64 channels. Modulation of alpha power was observed in parieto-occipital channels contralateral to the cued sequence. With no distractors, alpha desynchronization, or power decrease, occurred at each onset in the cued sequence only. A similar, but weaker, desynchronization pattern was observed in the one-distractor task. In the six-distractor task, however, desynchronization no longer occurred at target onsets, but at distractor onsets for all trials. An overall difference in power between active and passive trials was observed throughout both zero-and one-distractor tasks, but not in the six-distractor task. These results suggest that while top-down attention exerts strong modulation of alpha power, bottom-up attention can interfere, strengthening the response to non-targets while weakening the response to targets.

36.4024 **Temporal integration and spatial attention** Ilanit Hochmitz[1](ilanit57@gmail.com), Yaffa Yeshurun[1]; [1]University of Haifa

Recently, we found that sustained spatial attention increases temporal integration using the feature fusion paradigm. In the current study, we examined the effect of transient attention on temporal integration using a modified version of the Ternus display. In a typical Ternus display horizontally aligned disks are shifted by one position across alternating frames that are separated by a varying inter-frame interval. This display can induce two different motion percepts: one may perceive either three disks moving together (group motion) or two central static disks and an outer disk that jumps across them (element motion). Several studies suggested that spatial and temporal integration underlie these two motion percepts. According to this notion, element motion reflects temporal integration while group motion reflects spatial integration. We used a modified Ternus display, consisting of three frames with no inter-frame interval and oriented Gabor patches as elements. Temporal integration was manipulated by varying orientation similarity across frames. The orientation difference between the two frames varied between 0°- 45°. In the cued condition, a peripheral cue – a small bar – attracted transient spatial attention in advance to the patches location. In the neutral condition, a cue composed of four small bars did not indicate a location. Observers had to report which of the two motion percepts was perceived. As expected, the percentage of element motion report increased as the orientation difference between the frames decreased, supporting the hypothesis that element motion is mediated by temporal integration. Critically, we found a higher percentage of element motion report in the cued condition than the neutral condition. These results suggest that transient attention, like sustained attention, enhances temporal integration. We are currently also varying the intra-frame orientation difference with this version of the Ternus display to examine the effect of transient attention on both spatial and temporal integration.

36.4025 **Exogenous cues and visual confidence** Samuel Recht[1], Vincent de Gardelle[2], Pascal Mamassian[1]; [1]Laboratoire des Systèmes Perceptifs, Département d'études cognitives, École Normale Supérieure — PSL Research University, Paris, France, [2]Centre d'Economie de la Sorbonne, CNRS UMR 8174, Paris, France, Paris School of Economics, Paris, France

To which extent does visual spatial attention affect confidence judgment? Visual confidence refers to one's ability to estimate one's own performance in a considered task. As it relates to the second order representation of a primary decision, visual confidence might be considered as a form of metacognition. Hence, the ability of an observer to capture accurately her performance in a perceptual decision has been coined metacognitive sensitivity. Using an adapted version of a classic attentional paradigm, we investigated the effect of exogenous orienting of spatial attention on visual confidence and metacognitive sensitivity. Participants were instructed to fixate the center of a screen and to discriminate the orientation of a target consisting in a noisy 3-degrees Gabor patch displayed at 5-degrees eccentricity. Accuracy rates were titrated at the 75% threshold by adjusting target's SNR to each participant. To manipulate attention, the target was briefly presented at either the left or right side of the fixation point, on the horizontal mid-line. Both possible target locations were surrounded by four black dots (0.3° diameter each, 3° from target's center), equally spaced around each of the two possible target display areas. Prior to target onset, the dots at one side of the fixation cross ("cued location") were flashed (67ms). After a variable cue-to-target onset asynchrony (CTOA), the target was displayed during 50ms either at cued location or the other location. Following each trial, participants were prompted to estimate their probability of being correct with a confidence rating scale. Results showed a significant correlation between accuracy in orientation discrimination and confidence judgments ($p< 0.05$). These results suggest that observers were able to take into account the cueing effect despite a notable variation in metacognitive sensitivity along different CTOAs.

36.4026 **Working memory contents capture attention in real-world visual search** Shinyoung Jung[1](mental.zero@outlook.com), Yosun Yoon[2], Suk Won Han[1]; [1]Department of Psychology, Chungnam National University, [2]Department of Psychology, Chungbuk National University

Despite a large body of studies has demonstrated that stimuli matching working memory contents capture attention, an important limitation of these previous studies is that too much simplified and artificial stimuli were used. The present study investigated whether working memory contents capture attention in a setting that closely resembles real-world environment. In the experiment, participants performed a task of searching for a target object in a cluttered visual display, while maintaining a visual object in working memory. To create a setting similar to natural, real-world environment, we used images taken from IKEA's online catalogue. This catalogue included images of real-world, indoor scenes, such as living room, dining room, kitchen, and kids room. To create a real-world search task, we inserted a clock or a calendar in these images as the search target. Notably, the images of individual objects included in each scene were also available. These individual object images were served as memory samples. There were two different types of trials. In the memory-matching distractor trials, a memory sample was presented in the visual search display, whereas in the memory-nonmatching distractor trials, no memory object appeared in the search display. Importantly, participants were not informed about the presence of memory-matching stimulus in the search display. The results showed that the presence of memory-matching distractor significantly slowed search RT, $F(1,112)=14.45$, $p< .001$, suggesting that memory-matching stimuli captured attention in a real-world search. Notably, a significant RT difference emerged even when only the first pair of memory-matching distractor trials were compared with the first pair of memory–nonmatching distractor trials, $p < .005$. Given that participants did not expect the presentation of the memory-matching distractors a priori, this finding suggests that the observed capture took place, regardless of participants' intention. Taken together, memory-matching stimuli capture attention automatically in real-world visual search.

Acknowledgement: This work was supported by the Brain Korea 21 Plus Project in 2016.

ATTENTION: SPATIAL SELECTION

Sunday, May 21, 2:45 - 6:45 pm

Poster Session, Pavilion

36.4027 **Attention improves the perceived contrast of a uniform patch** Yong-chun Cai[1](yccai@zju.edu.cn), Zi-Yue Liang[1], Yi-Hui He[1]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University

Whether attention affects appearance is an important debate since the beginning of psychology. The debate has been intensified by the seminal work of Carrasco, Ling, & Read, 2004, indicating that the attention driven by abrupt onset can improve the apparent contrast of a grating. Because of using a comparing task, their results were thought to be contaminated by response biases. Some researchers did not found consistent facilitating effects of attention on appearance by using a bias-free task – the equal-

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ity judgment task (e.g. Schneider & Komlos, 2008). In addition, the cue of abrupt onset might induce attention-independent sensory interactions upon the following target and therefore interferes with the genius attentional effects. We examined how attention affects appearance in an experimental design with sensory interactions and response bias eliminated. Two rotating-dot surfaces were presented to the left and right of the fixation point. Attention was directed to one of the surface by briefly (200 ms) shifting the rotating dots upward or downward. Then the dots surfaces continued to rotate in the original direction for 100 ms and was followed by two gray target patches. We employed the bias-free equality judgment task (i.e., whether the two patches has the same luminance) to measure the PSE of the patch luminance on the valid or invalid side. The second task was to judge the shifting direction of the dots surface. The background was either black 0 cd/m2) or white (72 cd/m2). We found that the perceived luminance of the gray patch was attenuated by attention when the background was black, while it was boosted by attention when the background was white. These results indicate that attention improves the perceived contrast of a uniform patch, and cannot be explained by low-level sensory interaction and high-level response biases.

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36.4028 **Sensitivity measures of visuospatial attention** Nina Hanning[1,2](hanning.nina@gmail.com), Heiner Deubel[2], Martin Szinte[2]; [1]Graduate School of Systemic Neurosciences, Ludwig-Maximilians-Universität München, Munich, Germany, [2]Allgemeine und Experimentelle Psychologie, Ludwig-Maximilians-Universität München, Munich, Germany

Measuring visual sensitivity has become highly popular to determine the deployment of visuospatial attention. In this context, a variety of different stimuli and paradigms have been used. Our study aimed to evaluate the strengths and weaknesses of six types of these stimuli, frequently used as measures of visuospatial attention. While preparing an eye movement toward an endogenously cued target, ten participants discriminated a stimulus specific visual feature, either at the cued or at other equidistant locations. Stimuli differed both in visual features (oriented 1/f noise, flickering gabors and masks, random dot kinematograms, letters, crosses, and single gabors) and in the presentation mode (single onset stimuli or continuous visual stream). Discrimination signals were presented briefly (25 - 100ms) and at different time points (+/- 200ms relative to cue onset), along with an alternating number of distractors (three or seven). The paradigm allows to evaluate each stimulus in terms of temporal and spatial specificity, independence of set-size, as well as the influence of the discrimination signal on saccade metrics. Irrespective of stimulus type, we observed a clear increase of visual sensitivity at the cued location. Time course, spatial specificity and magnitude of this improvement however were specific to each stimulus. Moreover, single onset stimuli affected saccade metrics during eye movement preparation, with longer saccade latencies for signals played closer to saccade onset. Continuous stream stimuli, on the other hand, had no effect on saccade execution and thus should be favoured when studying the dynamics of visuospatial attention. All tested stimuli could properly measure visuospatial attention but differ in the criteria we examined. We present guidelines to chose the most suitable stimulus for a specific research question.

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36.4029 **Statistical learning of distractor suppression** Oscar Ferrante[1](oscar.ferrante@univr.it), Alessia Patacca[1], Valeria Di Caro[1], Elisa Santandrea[1], Chiara Della Libera[1,2], Leonardo Chelazzi[1,2]; [1]Department of Neuroscience, Biomedicine and Movement Sciences, University of Verona, Verona, Italy, [2]Italian Institute of Neuroscience (INN), Verona, Italy

The cognitive system has a remarkable capacity to extract and make good use of statistical information (statistical learning, SL), including for attentional guidance. In the attention domain, most SL studies so far explored the influence on performance of manipulating probability of target occurrence at various spatial locations. However, an emerging literature is starting to address changes in the efficiency of distractor suppression triggered by the unequal spatial distribution of distracting stimuli. Here we systematically assessed the latter form of learning. Our main focus here was to look for any interaction (cross-talk) between distractor suppression and target selection mechanisms; specifically, we wished to ask whether any changes in performance reflecting SL of distractor suppression would transfer to the efficiency of target selection across locations. In a series of experiments, participants had to report the pointing direction of an arrow target while ignoring a task-irrelevant salient distractor, when present (50%). While target probability was equal across locations, the distractor was more likely to appear at one particular display location and less at another location (and intermediate at two further locations). The results showed greater interference (capture) when the distractor was presented at the low probability location compared to any other location. Moreover, we demonstrated that this effect could not be explained in terms of inter-trial effects (e.g., repeated distractor location across consecutive trials). Importantly, although the target occurred equally often at all locations, the efficiency of target selection differed across locations, with faster responses for targets at the location with rare distractors. These results confirm that SL can modulate distractor suppression mechanisms. Furthermore, our findings indicate some degree of interdependence between distractor suppression and target selection processes, suggesting at least partly shared underlying mechanisms. The results will be discussed in relation to the notion of spatial priority maps.

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36.4030 **The precise role of surface structure in spatial attention** Nicole Jardine[1](nicole-jardine@uiowa.edu), Cathleen Moore[1]; [1]Psychological & Brain Sciences, Univeristy of Iowa

Visual attention operates on representations informed by surface structure (e.g., He & Nakayama, 1992). Surfaces can provide benefits that spatial information alone cannot. During search for a shape target among distractors, observers could not use spatial cues to prevent distraction from an additional color singleton outside the cued locations. They could, however, use surface cues to prevent distraction from color singletons on uncued surfaces (Vatterott & Vecera, 2015). This was a novel demonstration that surfaces can allow the attentional window to be configured to suppress noncontiguous locations, with significant implications for the processes that determine spatial selection and suppression. One concern about these displays, however, is displays with Surface structure contained more visual heterogeneity and differing contrast than those with Location cues. The differing levels of heterogeneity could produce the observed differing pattern of distraction for Location and Surface cues. In this set of experiments, we first replicated Vatterott & Vecera's findings. We then generated background stimuli that balanced the visual heterogeneity and clutter between Location and Surface conditions. The alignment or misalignment of components of these stimuli either formed or disrupted illusory object contours. Using these balanced displays produced a pattern of results different from those of Vatterott & Vecera. As such, the flexibility of spatial attentional control that is informed by surface structure remains an open question that our ongoing work examining covert and overt shifts of attention will answer.

36.4031 **Predictions, not attention, may modulate the first feedforward-sweep of cortical information processing** Josipa Alilovic[1,2](alilovic.josipa@gmail.com), Bart Timmermans[1], Leon Reteig[1,2], Heleen Slagter[1,2]; [1]Department of Psychology, University of Amsterdam, Amsterdam, The Netherlands, [2]Amsterdam Brain and Cognition, University of Amsterdam, Amsterdam, The Netherlands

Both attention (stimulus relevance) and expectation (stimulus probability) have been shown to alter information processing in primary visual cortex, suggesting that top-down influences can modulate the very first stage of cortical information processing. However, prior work either confounded attention and expectation, rendering their specific effects unclear, or used fMRI, which has low temporal resolution, leaving it unclear if these effects reflect a modulation of the first feedforward sweep of visual information processing or later, feedback-related activity. The current study orthogonally manipulated stimulus relevance and likelihood while exploiting the high temporal resolution of EEG to investigate if attention and/or expectation can modulate initial afferent activity in V1, as indexed by the early C1 component. Because the C1 is highly variable across individuals, for each participant we first determined two spatial locations at which the C1 could be reliably measured. Next, subjects performed an attentional cuing task in which they were cued on a trial-by-trial basis to direct their attention towards one of these locations and press a button whenever a target stimulus was presented at that location. The probability of a stimulus appearing

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at a given location was manipulated block-by-block, such that in different blocks the likelihood that a stimulus would appear was high (75%), neutral (50%) or low (25%). ERP analyses revealed that only stimulus probability, not stimulus relevance, may have an effect on the amplitude of the C1, which was larger for predicted stimuli and smaller for unpredicted stimuli, suggesting an effect of expectation, not attention, on the first feed-forward sweep of information processing. Our findings highlight the importance of studies that orthogonally manipulate attention and prediction to determine to what extent modulations of early sensory processing previously attributed to attention, can be ascribed to attention, prediction, or their interaction.

36.4032 The contra-lateral delay activity is reversed during the retention of episodic information

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The contra-lateral delay activity (CDA) is an ERP component associated with the maintenance of visual information in short-term memory. Negative electrophysiological activity in posterior cortical regions is stronger in brain hemispheres contra-lateral compared to ipsi-lateral to the lateral position of stimuli, indicating a spatial shift of attention towards the location of stimuli also during retention. While the CDA has been studied extensively as a representation of visual working memory capacity, it is still largely unknown whether the component is also a marker for the maintenance of episodic–that is, temporal, visual information. Here, we tested how episodic information is maintained in visual memory. In all experiments, participants encoded a temporal sequence of images and later reported the temporal position of target images within these encoded sequences. ERPs were measured during retention–that is, the interval between encoding and test, and the number of items to remember as well as the proportion of lateralized stimuli was varied within participants. Participants' accuracy performance was higher in conditions with small set sizes and in fully lateralized compared to partly lateralized conditions. ERP data supported these behavioral findings. However, the direction of the observed effects was the opposite of the direction of the classic CDA. In our experiments, the mean amplitude in lateralized conditions was more positive in contra-lateral than ipsi-lateral hemispheres. These findings challenge the view of the CDA as a general mechanism for the maintenance of visual information and suggest other, more task-specific, lateralized processes such as active suppression of spatial information to operate during the retention of information relevant to episodic memory.

36.4033 Spontaneous biasing toward implicitly-learned visual regularities: the role of prior attention

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To learn from our visual environment, we must constantly monitor for statistical regularities. Indeed, people even seem to spontaneously bias attention toward task-irrelevant regularities (Zhao, Al-Aidroos & Turk-Browne, 2013). Here, we question the extent to which this biasing depends on prior attention to regularities using a visual search paradigm. In the Training Phase, displays consisted of a 12-item "target set," containing a target T among Ls, and a 12-item "distractor set," containing only Ls. These sets appeared in red and blue, with the specific color-target mapping precued on each trial, enabling selective search. However, because of the frequent color switching, we expected participants would partially attend the distractor set; critically, we expected greater attention to the distractor set on trials in which the target color switched from the n-1 trial than when it repeated. To manipulate learning, unbeknownst to participants, we placed regularities in the distractor set (but never the target set). Specifically, every trial contained one of 16 invariant spatial configurations. 8 of these were only presented on color-switch trials, while the remaining ones were only presented on color-repeat trials. This allowed us to assess learning on trials with relatively high attention (color-switch) vs. on trials with relatively low attention (color-repeat). In the Test Phase, participants were no longer cued to the target set, so they now had to search both colors. Each display contained an invariant configuration in one color and a random configuration in the other. Results on trials containing a color-switch invariant configuration showed faster RTs for targets inside of this configuration than outside, demonstrating a clear bias toward a learned regularity. However, we found no inside/outside difference on trials with color-repeat invariant configurations. Therefore, the prior degree of attention to regularities predicts whether people will be biased toward them.

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36.4034 Independent mechanisms of spatial attention in visual and tactile working memory

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Are attention shifts in visual and tactile working memory (WM) controlled by a unitary supramodal mechanism or by separate modality-specific processes? To track the focus of spatial attention during the concurrent maintenance of visual and tactile information, we measured the visual and tactile contralateral delay activity (CDA/tCDA) components in WM tasks where two sample sets (S1 and S2) were presented sequentially. Participants memorized task-relevant target items in both S1 and S2 and judged whether these targets were presented again at memory test. In Experiments 1 and 2, S1 was bimodal and S2 was only presented in the primary modality (vision in Experiment 1, touch in Experiment 2). The primary-modality S1 and S2 targets were located on the same side or on opposite sides (stay versus shift trials, 50% each); participants performed the primary task alone (unimodal baseline) or additionally memorized stimuli of the secondary modality on the same side as the primary-modality S1 targets (bimodal condition). Shifts of attention in the primary modality were reflected by polarity reversals for the respective (visual or tactile) CDA in the period after S2. Critically, such attention shifts in the primary modality had no effect on the amplitudes and polarity of the tCDA/CDA evoked by the secondary-modality S1 targets in bimodal trials, indicating an independence of spatial selection mechanisms for tactile and visual information. In a third experiment, S1 and S2 were both bimodal and stay/shift trials were independently randomized per modality. Attention shifts in either modality reversed the polarity of the corresponding (visual/tactile) CDA, but did not influence the amplitude or polarity of the tCDA/CDA for the other modality. In conclusion, WM maintenance of visual and tactile information recruits spatially selective processes that operate independently and in parallel in both modalities.

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36.4035 Can synchronous multisensory looming stimuli bias attentional weights?

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Introduction. Previous studies suggest that spatially linked auditory and visual information has a higher likelihood to be further processed (Talsma, Senkowski, Soto-Faraco, & Woldorff, 2010) and that multisensory integration effects are more prominent in the elderly (Diaconescu, Hasher, & McIntosh, 2013; Laurienti, Burdette, Maldjian, & Wallace, 2006). These studies typically show that brief auditory stimuli affect detection of visual stimuli (e.g., Dalton & Spence, 2007). However, it is unclear whether multisensory stimuli can affect attentional weights when auditory and visual stimuli are integrated by their temporal synchronicity over a longer time period. To address this question, we developed a new paradigm examining whether we automatically assign higher attentional weights to stimuli with synchronous as opposed to asynchronous visual and auditory properties. Methods. Young (N=18) and elderly (N=28) volunteers participated in the study. They were asked to monitor two disks that continuously changed size either at the same or a different frequency. In 2/3 of the blocks, these visual disks were presented simultaneously with a sound that changed volume at either the same or a different frequency of one or both of the two disks. At random time intervals the luminance of one disk changed and participants had to detect this event as quickly as possible. Results. We predicted improved performance in the audiovisual synchronous compared to the audiovisual asynchronous and the no-sound condition. The results of 16 young observers illustrated an absence of this multisensory facilitating effect. The results were replicated in a group of elderly volunteers. Conclusion. Young and older observers do not automatically assign higher attentional weights to stimuli with synchronous audiovisual properties as compared to stimuli with asynchronous audiovisual properties.

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36.4036 **Attention Involved in Visual Search with Multiple Targets** James Wilmott[1](jpwilmott3@gmail.com), Joo-Hyun Song[1,2]; [1]Department of Cognitive, Linguistic & Psychological Sciences, Brown University, Providence, RI, [2]Brown Institute for Brain Science, Brown University, Providence, RI

From searching for car keys to looking for the doorknob in a dimly lit room, visual search is a ubiquitous everyday decision task. Prior studies have demonstrated that while distributed attention is sufficient for detecting an oddball target among distractors, focused attention is required for discriminating a fine detail (e.g., cut-off side of a target). However, this difference in the spatial scope of visual attention allocation has been mainly investigated with only a single target among varying numbers of distractors. Yet, this single target search represents only a subset of real world visual search scenarios. For example, X-ray and baggage screening require visual search when multiple potential targets are present. Here, we examine whether the distinct scopes of attention observed in detection and discrimination tasks with one target continue to be involved when there are two potential targets. In each trial we randomly presented one or two color oddball targets along with five or four homogenous color distractors, respectively. Participants were required to detect or discriminate one oddball target even when there were two targets presented. We observed that increasing the number of targets lead to longer reactions time in the discrimination task but did not have much impact on detection performance. These results suggest that in accord with a single target task, distributed and focal attention is involved while detecting and discriminating among search displays with two targets, respectively.

36.4037 **The distractor saliency and target detection for multiple RSVP series** Masataka Miyoshi[1](mstk344@gmail.com), Makoto Ichikawa[2]; [1]Chiba university, [2]Chiba university

In our preliminary study, we found that subjects more often failed to detect a second target in the lower visual field than in the upper visual field for multiple rapid serial visual presentations (RSVP) when each stimulus series were presented at both lower and upper visual fields. One may assume that the differences in target detection performance between upper and lower visual fields were mainly caused by their differences of attentional resolution which is higher at the lower visual field than upper visual field. In this study, we examined whether the saliency of stimulus affect the target detection in observing multiple RSVP series. Participants were required to detect two black alphabet targets (1.25 x 1.25 deg) embedded in two simultaneous black numeral RSVP series, which were presented at the 3 deg left or right from the central fixation cross on gray background. Each frame was presented for 100ms which contains 16.7ms interval. We manipulated the lag between the first and second targets (1, 2, or 6 frames), positional congruency for the two targets (congruent, or incongruent), and distractor saliency (low, or high), which was defined by luminance contrast against the background. We found that the frequency of the second target detection failure was high when the second target was embedded within the high saliency distractors while the first target was embedded within the low saliency distractors. However, the frequency of the second target detection failure was not so high when both of the targets were embedded in high saliency distractors. These results suggest that the strength of suppression in terms of distractors for the second target is determined by relative saliency of the distractors before the second target against the saliency of the distractors before the first target, rather than by the absolute saliency of the distractors before the targets.

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36.4038 **Invisible images of snakes and spiders capture visual attention** Xiaoyue Sun[1](sunxiaoyue14@mails.ucas.ac.cn), Lan Wang[1], Sheng He[1,2]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, [2]Department of Psychology, University of Minnesota, Minneapolis, United States of America

There was evolutional pressure for primates including humans to be able to rapidly detect threatening visual cues such as snakes. Highly selective snake-sensitive neurons were discovered in the Pulvinar of monkeys that respond with very short latency to visual images of snakes (Van Le et al. 2013). Here, adopting a modified Posner attention cueing paradigm, we investigated whether images of snakes and spiders could influence observers' spatial attention even when these images were interocularly suppressed and rendered invisible. All 44 subjects also completed questionnaires assessing their snake and spider fear (SNAQ, SPQ; FSpQ, FSnQ) (Klorman et al. 1974, O'Donohue 1995). Results show that indeed invisible snake and spider images could attract spatial attention. For invisible snake images, briefer presentation (e.g., 100ms) was more effective in attracting attention, but the attentional effect disappeared when snake images lasted for 500ms, while attentional effect remained for spider images shown for 500ms. Somewhat surprisingly, when visible, neither the spider nor the snake images showed significant attention cueing effect. Individual observers' snake fear score (FSnQ) correlated with attentional effect only in a visible condition (r=0.3161, p=0.0366). These results suggest that unconscious and conscious processing of visual fearful information may have different mechanisms. Unconsciously, images of snakes and spiders capture observers' attention regardless of whether they expressed high or low trait fear of snakes and spiders.

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36.4039 **Attention goes both ways: Shifting attention influences lexical decisions** Mark Mills[1](mark.mills2@huskers.unl.edu), Paul Boychuk[1], Jay Pratt[1], Alison Chasteen[1]; [1]Department of Psychology, University of Toronto

Considerable evidence exists that conceptual cues can influence the speed with which peripheral targets are responded to. For example, presentation of words related to the concept of divinity ("God", "Devil") facilitates responses to targets appearing at spatially compatible locations (e.g., "God" speeds responses to targets presented above fixation; "Devil" speeds responses to targets presented below fixation). The basic (but not thoroughly tested) premise underlying studies of conceptual cueing is that thinking of a spatial metaphor activates an internal spatial representation which, in turn, influences the allocation of attention in the external visual field. An important step forward in understanding conceptual cues is determining whether the underlying processes are bidirectional: do shifts of attention also facilitate the activation of corresponding conceptual information? To examine this issue, a brief peripheral cue was presented above, below, left, or right of fixation. After 100 ms, a string of letters was presented at fixation and participants indicated whether it was a word or non-word. Letter strings were either a conceptual word (e.g., "God") that was either compatible or incompatible with the location of the peripheral cue or were a matched pronounceable non-word (e.g., "jur"). If shifts of attention activate spatially compatible concepts, then shifting attention to a peripheral location should lead to faster word/non-word judgements of spatially compatible concepts, such that upward shifts lead to faster word/non-word judgements of up relative to neutral concepts while downward shifts lead to faster word/non-word judgements of down relative to neutral concepts (and likewise for leftward and rightward shifts). Our results support this prediction, suggesting that behaviors in the external visual field can influence the activation of internal representations.

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36.4040 **Effects of the number of distractor types on attentional blink** Misong Kim[1](msongkim@hallym.ac.kr), Soojin Lee[1], Hoon Choi[1]; [1]Department of Psychology, Hallym university

One of the most famous visual phenomena that reflect capacity limitation in temporal attention is attentional blink (AB), a deficit in identifying the second target in a rapid serial visual presentation (RSVP) when it is presented within 200–500 ms after presentation of the first target. A number of studies have explored various factors that affect AB, most of which were related to the targets. By contrast, we would like to focus on the natures of distractors. In the current study, we were interested in the effects of the number of distractor types. In the pilot experiment, we tried to check the difficulty levels of distractor types in terms of discriminability between targets and distractors. Four types of distractors (Japanese character, Chinese character, Korean character, and symbol) were employed, while a single type of target (a number) was used. Each RSVP consisted of one type of target and one type of distractor. We compared the AB effects for each distractor type; we found that three types of distractors (except for the Korean character) had similar difficulty levels and employed these three in the main experiment. In the main experiment, we manipulated how many types of distractors were used in one RSVP. We varied the number of distractor types in an

RSVP from one to three and then checked the AB effect. We had assumed that more distractor types would need more attentional resources, resulting in more substantial AB effects. The actual results, however, showed the opposite: AB increased when one type of distractor was employed in an RSVP. This result suggests that distractor heterogeneity may enhance our performance in temporal attention tasks, which is inconsistent with previous studies of spatial attention.

36.4041 Where is your attention?: Estimating the frequency of gaze following in the cuing task using a trial-by trial analysis. Christopher Blair[1](netiger@hotmail.com), Francesca Capozzi[1], Jelena Ristic[1]; [1]Department of Psychology, McGill University

Both laboratory and real world studies show that humans spontaneously follow the gaze of others. However, gaze following in the real world occurs surprisingly infrequently, only in about a third of available instances. Here we assessed whether the results from a typical laboratory based measure reflected consistent orienting of attention on most trials or an effect of averaging large performance differences on a handful of trials. To do so, we collected data from 25 participants who performed a gaze cuing procedure. Left or right gazing faces and a neutral face with closed eyes served as attentional cues. Participants detected peripheral targets, which occurred equally often at a left or right location. Data were analyzed in two ways. First, a standard group-based ANOVA replicated a wealth of past research showing overall reliable facilitation for gazed-at targets. Second, to address our questions, we calculated the proportion of gazed-at and not gazed-at trials that were significantly faster than baseline (i.e., closed eyes). We found that a greater proportion of gazed-at trials, i.e., 20% were faster than the baseline relative to 16% of not gazed-at trials. Taken together, these results suggest that performance in the gaze cuing task reflects neither consistent orienting throughout, nor the effect of averaging over several trials.

Attention: Individual differences, lifespan and clinical

Sunday, May 21, 2:45 - 6:45 pm
Poster Session, Pavilion

36.4042 Trait anxiety is associated with increased multiple-target visual search errors Matthew Cain[1](matthew.s.cain6.civ@mail.mil), Joseph Dunsmoor[2], Kevin LaBar[3], Stephen Mitroff[4]; [1]U.S. Army, Natick Soldier Research, Development, & Engineering Center, [2]New York University, Department of Psychology, [3]Duke University, Center for Cognitive Neuroscience, [4]George Washington University, Department of Psychology

Miss errors are a persistent problem in multiple-target visual searches. In particular, in displays with a mixture of high-salience and harder-to-find low-salience targets, low-salience targets are found less often when they appear with a high-salience target than if they are the only target present. These Subsequent Search Miss (SSM) errors (a.k.a. satisfaction of search errors), are a long-studied problem in radiology and security screening. These searches are both difficult and high stakes: miss errors could lead to fatalities. As such, they present situations where searchers may experience anxiety. SSM errors have been shown to increase when searchers are experiencing anticipatory anxiety (i.e., waiting for a random electrical shock while searching; Cain, Dunsmoor, LaBar, & Mitroff, 2011). Here, in three experiments, we extend these previous findings to show that not only does state-based anticipatory anxiety increase SSM errors, but also that trait-anxious individuals make more SSM errors than searchers with lower self-reported triat anxiety, even with no externally-added anticipatory anxiety. In the first experiment, we selectively recruited individuals who reported either high (N=22) or low (N=18) trait anxiety on the State-Trait Anxiety Inventory (STAI; Spielberger, 1983) in a prescreening questionnaire or previous lab visit. The high-anxiety group had significantly more SSM errors than the low-anxiety group ($t(35.328)=2.10$, $p=.043$, $d=0.67$). In a second, preregistered experiment, we recruited 74 participants without pre-screening and had them perform a multiple-target search task, followed by the STAI. SSM error rate and trait anxiety scores were positively correlated ($r(72)=.243$, $p=.037$). Finally, in a third experiment with 69 professional airport security searchers, SSM error rate was again positively correlated with trait anxiety scores ($r(67)=.251$, $p=.038$). Collectively, these results suggest that both acute anxiety caused by the task and chronic anxiety that the searcher brings with them to the task can make already difficult searches even more error-prone

36.4043 Dispositional affect predicts attentional and conceptual breadth: Individual difference evidence for the importance of arousal and valence interactions Andrew Chung[1](ac12fn@brocku.ca), Karen Arnell[1]; [1]Brock University

Abstract Several studies have investigated the effect of induced mood state on attentional and cognitive breadth. Early studies concluded that inducing a positive mood state broadened attention and cognition, while inducing a negative mood state narrowed these. However, recent reports have suggested that when valence and motivational intensity are unconfounded, low motivational intensity promotes cognitive breadth, whereas high motivational intensity promotes cognitive narrowing. Here we examine whether self-reported dispositional affect (using the circumplex affect questionnaire) can predict attentional breadth (using both the global-local Navon letter task and the hierarchical shape task) and conceptual breadth (using both the Remote Associates Test and an object categorization task), with no mood manipulations or cues. For all four tasks, results showed a valence-activation interaction. Participants low in activation (arousal) and high in positive affect showed the greatest cognitive breadth, and participants high in activation and high in positive affect showed the least cognitive breadth. Participants low in positive affect showed intermediate breadth that was not influenced by activation. In contrast to existing theories of cognitive breadth that highlight the importance of valence, or motivational intensity or arousal alone, the present results suggest that the combination of activation and valence is key to predicting individual differences in both attentional and conceptual breadth such that cognitive breadth decreases with activation, but only for those with high positive affect.

Acknowledgement: nserc

36.4044 Brooding rumination moderates sustained attention biases to emotion for non-depressed individuals. Max Owens[1](m-jowens@mail.usf.edu), Brandon Gibb[2]; [1]Department of Psychology, University of South Florida Saint Petersburg, Saint Petersburg, FL, USA, [2]Department of Psychology, Center for Affective Science, Binghamton University (SUNY), Binghamton, NY, USA

Both rumination and sustained attentional biases have been proposed as key components of the RDoC Negative Valence Systems construct of Loss. However, it is unclear whether the link between rumination and attentional biases is related to specific sub-types of rumination, and is observable independently of depression level. The current study examined the link between rumination and attentional biases in a sample of non-depressed individuals (n = 105). To assess sustained attentional biases, fixation durations were measured during a passive viewing task with 2 × 2 arrays of angry, happy, sad, and neutral faces. Higher levels of brooding rumination, a rumination sub-type associated with a negative self-focus, were associated with greater sustained attention to sad faces and less sustained attention to happy faces. Results remained significant after controlling for participants' prior history of major depression and current non-clinical level of depressive symptoms, suggesting a link between brooding rumination and attentional biases outside of depression.

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36.4045 Executive control processes can broaden attention for those with high approach tendencies Brent Pitchford[1](bp11lj@brocku.ca), Karen Arnell[1]; [1]Psychology, Brock University

Overriding one's dominant response tendencies by exercising self-control has been suggested to affect whether people see the "forest or the trees" (i.e., global/local bias), which is corroborated by evidence from both behavioural and electrophysiological measures. Since there are reliable individual differences in global/local processing, the extent to which the self-control exercise is producing this change - above and beyond the effect of people's individual differences in trait-like bias - is still unclear. Trait self-control and approach-motivated tendencies have both been suggested in past research to affect global/local processing. Here undergraduate participants viewed hierarchical letters (e.g., the letter F made of T's), both before and after completing incongruent (high self-control) or congruent (low self-control) colour Stroop tasks, and they were asked to report the target letters within the global and local levels of the images as quickly as possible. Also, participants completed self-report questionnaires to measure their general trait-like tendencies (e.g., Circumplex Affect Questionnaire, Behavioural Inhibition Scale; BIS, Behavioural Activation Scale; BAS, Self-Control Scale, Impulsivity Scale). Results showed that there was only a significant change in global bias (Local RT – Global RT) during the incongruent condition relative to the congruent condition when considering participant's approach-like tendencies; higher BAS and lower BIS participants tended to show a greater global bias after the self-control task compared to the pre-Stroop baseline, relative to people with lower BAS and higher BIS scores. The findings from this study provide further support that approach-motivated tendencies are integral to better understanding the effect that executive functioning has on global/local bias.

36.4046 **Visual Attention and Visual Memory in Struggling Readers: Are Anomalies Revealed in ERP N2pc and SPCN?**

Richard Kruk[1](krukr@ms.umanitoba.ca), Erica Flaten[1]; [1]Department of Psychology, University of Manitoba

Children with reading difficulties often show deficits in selective visual attention (SVA), and in encoding visual information into visual working memory (VWM). We analyzed the ERP N2pc wave component, representing SVA, and the SPCN component, representing successful VWM storage, in good- and poor-reading children while they performed an object-substitution masking (OSM) task. During OSM an illusory object elicited by a mask replaces the target stimulus, particularly with delayed mask offset. Thus, we predicted that storage of the target into VWM would be hindered under delayed mask offset. Because poor readers tend to show anomalous encoding into VWM, we expected to see a reduced SPCN in these individuals. Previous research indicates that N2pc is found for both incorrect and correct trials with delayed but not with co-termination offsets. We therefore expected to find N2pc in delayed-offset trials, and that the amplitude would be reduced in poor readers due to SVA anomalies. In support of our hypothesis, results showed that N2pc was reliably elicited in children in delayed offset conditions, and suggested greater load on SVA resources in the delayed conditions in poor readers. Visual analysis of the wave components indicated SPCN in correct trials, representing successful storage of the target into VWM. Results on reading group differences are discussed in relation to current conceptualizations of SVA anomalies in poor readers.

Acknowledgement: University of Manitoba

36.4047 **Individual differences in neural representations of accumulating affective information**

Andre Beukers[1](andre_beukers@hotmail.com), Mana Ehlers[1], James Kryklywy[1], Sarah Moore[2], Adam Anderson[2], Rebecca Todd[1]; [1]Psychology Department of the University of British Columbia, [2]Department of Human Development of Cornell University

How does the emergence of a neural representation of affective salience differ between individuals? Previous research has shown that with successful aversive conditioning visual representations of two conditioned stimuli can converge [1]. Here we used representational similarity analysis (RSA) of fMRI data to study individual differences in the changes that accrue to the representations of visual stimuli over the course of emotional learning. Participants were scanned during a Pavlovian conditioning task using both aversive and pleasurable reinforcers in a slow event-related design. In separate blocks, participants learned to associate two individual faces with either a painful pinch or pleasurable brush stroke (CS+), while a third face remained unreinforced (CS-). Faces were rated for likability before and after conditioning and participants were grouped into conditioners and non-conditioners based on changes in likability ratings. Ventromedial prefrontal cortex (VMPFC) and ventral visual cortex regions of interest (ROIs) were anatomically defined. For each ROI, multivariate representational similarity matrices were calculated using the patterns of activation for each stimulus presentation. Finally, inferential statistics were performed to evaluate similarity of adjacent trials within each stimulus category and of corresponding trials between different stimulus categories. Results showed that in the VMPFC, similarity of representations for CS+ stimuli steadily increased during learning for conditioners only. Furthermore, the representations of the two CS+ stimuli became more similar for conditioners than non-conditioners. This suggests such a convergence in stimulus representation is driven by affective processes. This pattern was not observed in the ventral visual ROI, suggesting a dissociation between how affect information accumulates over time in PFC compared to ventral visual regions. The nature of such affect-driven information accumulation was further probed through exploratory RSA on ROIs defined by specific resting state networks.

36.4048 **The effects of acute stress on the attentional network.**

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The potential for acute stress to alter normal cognitive functioning is well reported (McEwen & Sapolsky, 1995). For attention, evidence for the nature of this change – whether advantageous (Helton et al., 2009) or detrimental (Scholz et al., 2009) – is conflicted. The current study investigated the effects of acute stress on attention using the revised Attentional Network Task (ANT-R) (Fan et al., 2009) and the Socially Evaluative Cold Pressor Task (Schwabe et al., 2008). Before the stressor, baseline performance on the ANT-R was taken. After the stressor, or comparable control, ANT-R performance was measured in line with two known physiological reactions following stress (Sympathetic Nervous System (SNS) and Hypothalamic-Pituitary Adrenal Axis (HPA) activation). Subjective and physiological stress measures were recorded to assess state, with anxiety (SSAI, Spielberger, 1989) and an adapted NASA-TLX (Hart & Staveland, 1988) demonstrating that stress was successfully induced (physiological measures awaiting assay). ANT-R measures showed, for the stress group, a benefit in alerting (RT) and a cost for inhibition of return (IOR, accuracy) in the SNS time period. Both effects remained when including baseline measures for trait anxiety (STAI, Spielberger, 1989) Intolerance of Uncertainty (IUS-12, Carleton et al., 2007), spatial working memory (Shackman et al., 2006) and gender as predictors, but did not remain after correction for multiple comparisons. There was some evidence for gender mediating the effects of stress on SNS and HPA ANT performance, which did not remain when individual trait differences were included. No differences were found for other ANT-R measures ($p\eta^2$ = .000 to .056, power = .052 to .512). The results present some resolution to previous conflicting findings, suggesting that the SNS response to stress affects attention in both advantageous (alerting) and detrimental (IOR) ways. However, it provides minimal evidence of effects of acute stress on attention during the HPA reactivity period.

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36.4049 **Patterns of cortical microstructure predict visual sustained attention ability**

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Several studies have examined how individual differences in sustained attention relate to functional brain measures (e.g., functional connectivity), but far fewer studies relate sustained attention ability, or cognition in general, to individual differences in cortical microstructure. FMRI meta-analyses and patient work have highlighted that fronto-parietal regions, lateralized to the right hemisphere, are critical to sustained attention, though recent work implicates a broader expanse of brain regions (e.g., Rosenberg et al, 2015). The current study sought to determine if and where variation in cortical thickness is significantly associated with sustained attention performance. Further, using multivariate modeling, we examined whether regional patterns of cortical thickness could predict individual differences in performance. Neurologically-intact adult participants (n=118) performed an 8-minute continuous performance go/no-go sustained attention task (gradCPT) after acquiring two high-resolution structural MRI scans. A whole brain analysis, controlling for age differences, revealed that thicker occipital and temporal regions correlated with better sustained attention ability (d-prime and RT variability). On the other hand, variation in sustained attention strategy (response criterion and mean RT) was only weakly related to cortical thickness. Similarly, multivariate classifica-

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tion analyses using whole-brain patterns of thickness were able to reliably predict individual differences in gradCPT ability, but not strategy. Further analyses revealed that right hemisphere regions were most important for predicting performance, and that performance was also related to relative thickness differences between homologous regions of the right and left hemisphere. While these results partially coincide with fMRI studies (e.g., right lateralization), they do not implicate microstructure in the classic attention networks (e.g., dorsal attention network) as being most critical for explaining individual differences. Instead this indicates that the microstructure in areas typically associated with vision and memory may contribute to sustained attention, and more broadly that structural variation may complement functional variation in the study of individual differences in cognition.

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36.4050 **Did You See That?! A Look Into Whether Media Engagement Can be Influenced by Individuals' Viewing Styles.** Taylor Simonson[1](simonsont@findlay.edu), Adam Larson[1]; [1]University of Findlay

Research has shown that top-down processes produce different eye movement patterns when searching scene images (DeAngelus & Pelz, 2009; Yarbus 1967). However, do these same top-down processes extend to film stimuli? Researchers have theorized that viewers have different modes of reception, such that some viewers become emotionally engaged in film, whereas others do not (Michelle, 2007; Suckfull & Scharkow, 2009). This indicates that individual differences in reception would produce different eye movement patterns while viewing film. Conversely, recent research shows similar eye movement patterns, even though the viewer's comprehension of the film differed (Loschky, Larson, Magliano, & Smith, 2015). This research suggests an alternative hypothesis that bottom-up saliency in film would produce similar eye movements. The current experiment was designed to determine if viewer engagement would predict eye movements in short film clips. Emotional engagement was manipulated by presenting emotional versus non-emotional clips. Five emotional clips were presented to participants that depicted a suspenseful scene, whereas seven non-emotional clips depicted conversations between two or more individuals. Film clip durations ranged from 30 to 160 seconds. After each clip, participants were asked to rate how engaging/emotional it was on a five point Likert scale (1 = not engaging; 5 = engaging) and if they had seen the clip before. Scanpath scores were calculated for each participant, which measured the degree to which participants fixated on the same location at the same time compared to the remaining participants. The results show that emotional film clips were negatively related to scanpath scores, indicating that the bottom-up, emotional content depicted in film was associated with dissimilar scanpaths. Conversely, viewer engagement was positively related to scanpath scores, such that similar scanpaths were associated with increased film engagement. Thus, attentional selection processes while viewing film was influenced by both bottom-up and top-down processing.

36.4051 **Useful field of view performance throughout adulthood** Karlijn Woutersen[1](k.woutersen@donders.ru.nl), Thomas Theelen[2], Jeroen Goossens[1]; [1]Radboud University Medical Centre, Donders Institute for Brain, Cognition and Behaviour, Cognitive Neuroscience, [2]Department of Ophthalmology, Radboud University Medical Center

The useful field of view (UFOV) test is a computerized test that measures the amount of information someone can extract from a visual scene in one glance. It consists of three subtests and its scores show relatively strong relations with everyday activities such as driving. UFOV performance decreases in several visual conditions as well as with ageing and can be improved by training. However, studies have mainly focused on elderly and patients. Few studies have investigated healthy subjects under the age of 50 years. In the current study, we examine UFOV performance throughout adulthood. In addition, we investigate which visual and neural processes underlie changes in performance related to ageing. To that end, we included 46 adults aged 18 to 70 years who reported no visual problems. Participants underwent a thorough visual screening. In addition, we obtained several psychophysical and electrophysiological measures at various levels of the visual system. Specifically, we measured retinal responses using multifocal electroretinograms, early visual processing with onset and pattern visual evoked potentials and cognitive processing with an oddball paradigm. As expected, we found an age related decline in total UFOV performance, that is, scores became higher with increasing age. This effect seems mainly driven by the third UFOV subtest. The first and second subtests show less variability, with performance being very high in general for these tests. The age-related decline seems unrelated to visual acuity. Furthermore, preliminary analyses of the electrophysiological measurements indicate that low-level neural processing of visual stimuli remains unchanged. This suggests that the age-related decline in UFOV performance may be due to diminishing higher-level neural processes.

36.4052 **Adult age differences in phasic alerting effects on components of visual attention** Iris Wiegand[1,2,3](wiegand@mpib-berlin.mpg.de), Anders Petersen[1], Claus Bundesen[1], Thomas Habekost[1]; [1]Center for Visual Cognition, Department of Psychology, University of Copenhagen, [2]Max-Planck UCL Centre for Computational Psychiatry and Ageing Research, [3]Center for Lifespan Psychology, Max-Planck Institute for Human Development

Visual attention is a multi-component function that underlies effective behavior in our visual environment. Thus, age-related changes in visual attention can cause difficulties in many every-day tasks. Alertness, the system's state of general readiness to react to sensory stimuli, is closely linked to the efficiency of visual attention. However, which components of attention are affected by alertness, and how this changes with aging, is unclear. In the present study, we investigated effects of phasic alerting on distinct parameters of visual attention based on the computational Theory of Visual Attention (TVA). In groups of younger and older adults, we modeled parameters in a partial report task, in which half of the displays were preceded by an auditory warning cue. We further measured visual event-related lateralizations (ERL) to derive neurophysiological correlates of the alertness and age effects on visual processing stages. Younger adults showed an alertness-related processing facilitation: Parameter sensory effectiveness a, a measure of visual processing capacity, was significantly increased. The behavioral effect was accompanied by a latency reduction of the ERLs following the warning cue, indicating speeded resource allocation to visual processing areas. By contrast, older adults did not benefit from the alerting cue: Parameter sensory effectiveness a, and ERL latencies, were not modulated by the cue. The relative distribution of processing capacity according to spatial locations and task-relevance, reflected in parameters spatial bias windex and top-down control a, respectively, were unaffected by phasic alerting in both age-groups. The findings are in accordance with a recent extension of TVA, claiming that phasic alertness increases the overall processing capacity by multiplying all neural activations representing visual categorizations with a common factor. They further indicate age-related changes in the brain network underlying alertness and attention, which governs the responsiveness to external cues and is crucial for general cognitive functioning in aging.

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36.4053 **Don't Overreact to this! Over-reactivity of the M-pathway in Older Adults** David Chan[1](davidyt.chan@mail.utoronto.ca), Liza Igochine[1], Jay Pratt[1]; [1]Department of Psychology, University of Toronto

The role of aging on cognitive decline has been looked at with a great deal of interest over the past few decades. Mainly, the aging literature has focused heavily on the impact of aging on memory and cognitive resources. However, one area of literature that remains underdeveloped has been the role on how aging affects the cognitive processes of vision, more specifically how aging changes the mutually inhibitory processes of the magnocellular (M) and parvocellular (P) pathways. Therefore, in order to test how aging affects these two visual pathways, we implemented techniques known to hinder or bolster the M-pathway in younger adults with older adults. In Experiment 1, we tested if the inhibition of the M-pathway with a pulsed pedestal design also occurs with older adults. In this task, we had younger and older adults perceive low and high spatial frequency gabors with either a pulsed or steady visual pedestal. In Experiment 2, we examined if the connection between the M-pathway and action processing found in younger adults changes with age. To do so, we adapted the same design but with action and non-action oriented objects instead of gabors. Across these two experiments, older adults showed a greater deficit in processing low spatial frequency gabors and action objects under the pulsed pedestal

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condition compared to younger adults. In Experiment 3, we examined if placing the hands proximal to visual images, which facilitates M-pathway processing in younger adults, also occurs for older adults. Here we found that older adults showed the opposite effect; greater advantage for low spatial frequency Gabors compared to younger adults when the hands were proximal. The data across all three experiments suggest that older adults may have overactive M-pathways, with larger deficits when the M-pathway is inhibited and larger benefits when the M-pathway is bolstered.

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36.4054 Endogenous and exogenous covert attention are functionally intact in adults with ADHD Mariel Roberts[1](mariel.roberts@nyu.edu), Brandon Ashinoff[1,2], F. Castellanos[3], Marisa Carrasco[1,4]; [1]Department of Psychology, New York University, New York, NY, USA, [2]School of Psychology, University of Birmingham, Edgbaston, Birmingham, UK, [3]NYU Child Study Center, Department of Child and Adolescent Psychiatry, New York University Langone Medical Center, New York, NY, USA, [4]Center for Neural Science, New York University, New York, NY, USA

Purpose. Is visuospatial covert attention –the selective processing of visual information in the absence of eye movements– preserved in adults with Attention-Deficit/Hyperactivity Disorder (ADHD)? A few studies suggest that the effects of attention on early visual processes in adults with ADHD resemble neurotypical adults. However, imprecise terminology, variability in experimental design and reliance on only reaction time limit these conclusions. To address these limitations, we used spatial cueing protocols that have been well-established in neurotypical and special populations to assess accuracy and speed of processing in a basic visual task. Methods. We adjusted stimulus contrast to equate task difficulty across individuals in a neutral, distributed cue condition. Fourteen ADHD adults and 14 age- and gender-matched controls performed a 2AFC orientation discrimination task. We manipulated exogenous (Experiment 1) or endogenous (Experiment 2) covert spatial attention via presentation of a peripheral or central spatial cue, respectively. Eye fixation was ensured. Attentional "benefits" (Experiments 1 & 2) and "costs" (Experiment 2) were calculated relative to the neutral condition. Results. For both groups, attention significantly improved accuracy and decreased reaction times to a similar extent in both experiments. Moreover, deployment of endogenous attention away from the target location significantly impaired accuracy to the same degree (Experiment 2). Only the ADHD adults demonstrated a reorienting hemifield asymmetry, i.e. significantly slower responses to targets when the invalid cue was on the right than left visual field. Both groups performed better along the horizontal than vertical meridian as well as lower than upper vertical meridian, and showed similar effects of attention at all isoeccentric locations. Conclusion. Despite the disorder's name, in adults with ADHD both endogenous and exogenous covert spatial attention remain functionally intact for basic visual tasks. Moreover, they exhibit the same perceptual asymmetries and attention effects around the visual field as neurotypical observers.

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36.4055 Sustained visual attention at different retinal eccentricities and its significance for the development of the preferred retinal locus Maria Barraza-Bernal[1](maria.barraza-bernal@uni-tuebingen.de), Iliya Ivanov[1], Katharina Rifai[1], Siegfried Wahl[1]; [1]Institute for Ophthalmic Research, Eberhard Karls University, Tuebingen

The ability to deploy visual attention within the visual field varies among different angular positions at equal eccentricities. The selection of the preferred retinal locus of fixation (PRL) is influenced by the high ability to deploy visual attention to a discrete location within the visual field. Most of the maculopathies that lead to PRL development are progressive and as a consequence, PRLs are constantly relocated. A tendency to locate the PRL on the same meridian has been described. Their constant relocation of PRL on the same meridian might be also governed by attentional mechanisms. Thus, this study investigates the variations of sustained visual attention at different eccentricities of the visual field. Four normally sighted subjects participated in the study. Their sustained attention was measured at three different eccentricities of the visual field. The three eccentricities measured were 3.5°, 5° and 6.8° of visual angle. In each measurement, subjects had to report the orientation of a Snellen E presented on a previously cued location. Eight discrete locations on the visual field with a step size of 45° were tested. The results showed a preservation of shape of the attentional performance fields across the different retinal eccentricities. The absence of variations on the shape of the performance fields supports a link between sustained attention and the PRL along the same visual field meridian. These results might contribute to the development of new therapies of progressive central maculopathies.

36.4056 The role of naturally occurring differences in norepinephrine availability in modulating electrocortical indices of affectively biased attention Maria Manaligod[1](mariagm.manaligod@gmail.com), Kevin Roberts[1], Matthias Wieser[2], Daniel Mueller[3], Rebecca Todd[1]; [1]University of British Columbia, Canada, [2]Erasmus University Rotterdam, Netherlands, [3]Centre for Addiction and Mental Health Canada

It is well established that emotionally salient stimuli implicitly guide attention and enhance visual cortex activation. Yet when emotional salience is pitted against task-relevant goals, mixed effects have been observed, with salient stimuli sometimes hampering task performance (competition), and sometimes improving it (facilitation). Non-human animal research suggests norepinephrine (NE) plays a role in enhancing the gain of neural populations tuned to both affectively salient and goal-relevant stimuli. In humans, genotyping for a common (~50%) deletion variant of the ADRA2b gene, which codes for alpha2b NE receptors, provides a window into the role of NE availability. The goals of the present study were: (1) To examine allocation of cortical resources to task demands in the presence of emotionally salient distractors, and (2) to employ genotyping to explore the role of noradrenergic processes. We measured steady-state visual evoked potentials (ssVEPs) during a change detection task wherein task-relevant Gabor patches were overlaid on task-irrelevant happy, angry, or neutral faces. The overlapping stimuli were driven at distinct frequencies (15 Hz or 20 Hz, counterbalanced within participants). Observers were asked to report phase reversals in the Gabor patch and ssVEP amplitude at driving frequencies was extracted to measure allocation of attention. Observers showed greater accuracy and higher ssVEP amplitudes for targets overlaid on angry faces than on happy or neutral faces, indicating a pronounced facilitation in the presence of negative stimuli. ssVEP amplitudes for faces showed an effect of arousal, with higher amplitudes for happy and angry faces, suggesting there was not a trade-off between resources allocated to targets vs. distractors. Preliminary genotyping results (N = 126) indicate that carrying the ADRA2b deletion variant enhanced the facilitation effect, suggesting that, rather than playing a requisite role, greater NE availability functions to enhance existing patterns facilitation of focused attention by negative affect.

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36.4057 Orientation surround suppression but not complex search slope correlates with autistic trait level. David Crewther[1,2](d-crewther@swin.edu.au), Rong Ye[1], Yasi Jian[1], Hsin-yi Lai[1]; [1]ZIINT, Zhejiang University, [2]CHP, Swinburne University of Technology

The typically developing (TD) population shows perceptual and physiological differences (global/local perception, motion coherence, flicker fusion, magnocellular function) in the typically developing (TD) population related to the degree of autistic traits. However, some have questioned whether Baron-Cohen's AQ is tapping clinical ASD, where children with autism show precocious skill in visual search, as well as differences in global/local visual perception. Here, we measured visual search and cross orientation surround suppression (COSS) in18 young adults (20-29 yr) of mixed sex. They completed a Chinese translation of the AQ (English form alongside). In the search task (present/absent 2AFC), a 2x2 array of parallel line segments was embedded in an array (9, 16, 36, 81, 169, 400 elements) of randomly oriented lines. In the COSS task, one of four annular segments containing gratings would appear with less contrast than the others. The neighbouring regions were either parallel or perpendicular in orientation. Just noticeable difference thresholds were obtained for low (.5 cycles per degree) and high (3.0 cycles per degree) spatial frequency gratings. The suppression index showed significant negative correlation with AQ score (RSquare(18) =0.27, p=.0267) for the HSF task, but not for the LSF task (RSquare(18) =0.009, p>0.7). For the visual search task, reasonable RT/set size linearity was observed except for the largest set which was excluded from analysis. Statistical comparison of linear fits showed no significant correlation between reaction times slope per item and AQ score, whether for target present (RSquare(18) =0.0067, p=.75) or target absent trials (RSquare(18) =0.057, p=.337). It is possible that the two tasks tap different neural systems. Social disorganization common to those with high AQ and schizotypal personality (SPQ) scores, potentially links to clinical findings in schizophrenia, where reduced COSS and reduced GABA concentration in visual cortex form markers of reduced inhibition.

Acknowledgement: ARC

36.4058 Increased Preceuneus deactivation as a possible mechanism for enhanced preparatory suppression in people with high expression of autistic traits

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Previous evidence point to atypical attention processes in autism (and the broader autistic spectrum in neurotypical participants) particularly in conditions requiring distractor suppression. Further characterizing this atypicality, we have recently proposed (Abu-akel et al., 2016; Abu-Akel et al., VSS 2016) that Autistic traits are associated with a benefit when suppressing distractors in a preparatory manner but impairment when distractors are inhibited reactively (when more dynamic control of attention is required). In the present study we consider the Precuneus (Pc) as a candidate brain mechanism that may explain such a preparatory bias. The Pc is a potential candidate here as its deactivation (within the default mode network) is thought to facilitate performance in a preparatory way while its activation is thought to support dynamic switching between stimulus' aspects (Serences et al., 2004). To test whether Pc deactivation may explain preparatory biases in people with higher expression of autistic traits we assessed these traits in a total of 211 neurotypical adults who performed a blocked Global/Local task where target and distractor levels were known in advance (preparatory suppression). Next we examined the effect of Pc deactivation on task performance in a new cohort of ten participants using offline TMS over the Pc. We found reduced distractor interference in adults with high expression of autistic traits in the Global/Local task, irrespective of target level (global or local) or its relative salience. Importantly, a similar reduction in distractor interference was evident following TMS over the Pc, which again occurred irrespective of target level or saliency. Our findings point to the Pc as a potential brain mechanism underlying improved preparatory suppression. We speculate that high expression of autistic traits may be associated with increased deactivation of the Pc which in turn facilitates preparatory distractor suppression but is detrimental when dynamic control is needed.

36.4059 SALICON: a web platform for crowdsourcing behavioral experiments

Ming Jiang[1], Zhiqi Shen[2], Shaojing Fan[2], Qi Zhao[1]; [1]University of Minnesota Twin Cities, [2]National University of Singapore

Laboratory experiments for human behavioral studies lack scalability or generality, making big cognitive studies non-trivial especially with complex natural scenes or less controlled environment. To tackle this issue, we propose a web-based behavioral experiment platform for crowdsourcing large-scale behavioral data. The main target of the platform is focused on the area of visual attention. It provides an inexpensive and easy-to-use method for scalable data collection relating to image perception and visual attention. Core features include a mouse-tracking experiment to simulate eye tracking with mouse or finger movements, an image annotation experiment to characterize complex stimuli, and a general survey. Experimenters set up studies on this platform using customized templates of these experiments. The platform also allows experimenters to publish their experiments on Amazon Mechanical Turk with simple configurations. Experimental results are available for download and visualization at any time.

36.4060 A correlational study between human attention and high-level image perception

Shaojing Fan[1](fanshaojing@gmail.com), Ming Jiang[1], Juan Xu[1], Bryan Koenig[2], Yao Cheng[1], Mohan Kankanhalli[1], Qi Zhao[3]; [1]National University of Singapore, [2]Washington University in St. Louis, [3]University of Minnesota

People have a remarkable ability to attend selectively to one or a few sensory inputs while ignoring the other ones (J. Moran, & R. Desimone, 1985). Although many studies have been made on selective attention at object level (T. Brosch, G. Pourtois, & D. Sander, 2010), less is known about the human attention and visual perception on complex natural scenes. We studied the correlation between human attention and visual perception of images of natural scenes. Sixteen subjects (mean age = 27) freely viewed 1249 emotional images and had their eye movements recorded. Another group of 358 participants viewed the same set of images and annotated a comprehensive list of 33 scene-level attributes, which includes 10 emotions (happiness, surprise, awe, excitement, amusement, contentment, sadness, anger, fear, and disgust) and 23 other attributes commonly studied in computer science community (e.g., aesthetics, image quality). Analyses indicated the following relationships among observer fixation patterns and image attributes: (1) Human has generally longer fixation duration and saccade duration on images with positive sentiments (e.g., aesthetics, awe), but shorter fixation on images with negative sentiments (e.g., sad, disgust). (2) Human has a general shorter saccade length and lower saccade velocity on images that are more centered and symmetric. (3) When an image is of high quality or having focused object, it will usually lead to shorter saccade duration and higher saccade velocity of its observer. In summary, we found that image semantics, sentiment, and spatial layout correlate with human fixation patterns in a significant way. Our method is general and comprehensive in the sense that it focuses on complex natural scenes and studies on an intensive attribute lists.

PERCEPTION AND ACTION: WALKING AND NAVIGATING

Sunday, May 21, 2:45 - 6:45 pm
Poster Session, Pavilion

36.4061 Walkers prefer to visually sample the upcoming terrain during the critical phase for visual control of foot placement

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When humans walk over complex terrain, they do not need to continuously sample the upcoming ground surface. Even a brief glimpse is sufficient for accurate foot placement if the relevant information is sampled precisely when it is needed to initialize the upcoming step. Previously, we showed that the critical phase for the visual control of foot placement on a given target is the last half of the preceding step. The aim of the present study was to examine whether walkers' preferences for when to sample the upcoming terrain are aligned with the predictions of the critical phase hypothesis. Specifically, we tested the prediction that subjects prefer to sample the upcoming terrain during the same portion of the gait cycle at which sampling is most useful for the accurate control of foot placement. Subjects were instructed to walk along a path of irregularly spaced virtual targets (small patches of light projected onto the floor) while their movements were tracked by a motion capture system. The visibility of each target was manipulated such that targets were only visible for a brief period (e.g., ½ step). The key manipulation was the timing of visibility. Targets could appear and disappear when they were as far as 2 ½ to 2 steps ahead or when they were as close as ½ to 0 steps ahead. After each trial, subjects indicated whether targets were visible earlier or later (farther or less far in advance) than they would have preferred. The results indicated that subjects preferred to sample information about the upcoming targets around the same time that sampling allows for accurate foot placement. The findings could inform our understanding of how walkers decide when to sample the upcoming terrain in situations in which they also need to fixate of other regions of the visual environment.

Acknowledgement: NSF 1431078

36.4062 The visual control of walking over complex terrain with flat versus raised obstacles

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When humans walk over terrain with irregularly spaced flat obstacles, such as puddles or patches of ice, visual information about the locations of those obstacles is needed at least two step lengths in advance of foot

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placement to avoid collisions and energetically costly adjustments to the natural gait cycle (Matthis and Fajen, 2013, 2014). However, obstacles found in natural environments are not always flat and the height of an obstacle, as well as its location, constrains how the feet must be moved to successfully avoid a collision. The aim of the present study was to determine how the presence of raised obstacles affects how far ahead walkers need to see to avoid collisions and maintain walking speed and energetic efficiency. Subjects traversed a short path over virtual complex terrain comprising irregularly spaced obstacles. The virtual scene was projected onto the floor using a 3D-capable projector that rendered a stereoscopic image at 60fps per eye. When viewed while wearing LCD shutter glasses, subjects experienced the illusion of terrain with variations in surface elevation. This paradigm was developed and validated by Diaz, et al. (2015) as a means of providing realistic, stereoscopic visual information without an HMD and allowing for natural obstacle avoidance behavior. To evaluate when visual information is necessary for successful locomotion, we created a traveling window of visibility centered on the subject's head and made obstacles visible only when they fell within the window. The key manipulations were the size of the visibility window, which ranged from 1.0 to 5.0 step lengths, and whether the obstacles were 3D or flat. The results reveal how variations in the structure of the environment affect how far in advance walkers begin to use visual information about the upcoming terrain as well as their ability to exploit their inverted-pendulum-like structure.

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36.4063 Obstacle Avoidance and Secondary Task Performance During Locomotion

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In the US, 1,506 people were treated in emergency room for an injury caused due to using cell while walking, in 2010 (Nasar, 2013). The underlying mechanisms for interference of locomotion by a secondary task is not well understood. Studies suggest "in-attentional blindness" contributes (Hyman 2010; 2015) but have not addressed walking biomechanics. Biomechanically, people walk more "cautiously" while using cell phones (Lambert, 2012; Cha, 2015; Haga, 2015) but collisions are not studied. Additionally, walking is affected by attention and executive function (Seligmann, 2008). This study investigated the effects of performing a secondary task (on cell phone) on the ability to avoid obstacles while walking, and the impact of executive function on performance. Thirty young adults walked on a treadmill and negotiated virtual obstacles by shifting laterally, while playing a game on a cell phone. Cognitive capacity was quantified, using PEBL Perceptual Vigilance Task and Berg's Card Sorting Test. The cell phone task led to a 6.45% increase in the time taken to avoid obstacles (Movement Time), and 44.11% increase in the variation in Movement Time (Standard Deviation of Movement Time). There was a significant increase in the number of collisions due to cell phone use. Individuals with higher Reaction Time and Failure to Maintain Set had higher Percent Collisions; individuals with higher cognitive flexibility performed better on the cell phone task. There was a significant but weak correlation between baseline cognitive measures and performance on the secondary and the locomotion task, only when both the tasks were performed simultaneously. Performing a secondary task during locomotion causes an increase in collision, delay in response and increase in the variability of response to obstacles. Moreover, ability to avoid obstacle and perform the secondary task while walking depends on executive function.

36.4064 Does uncertainty about the terrain explain gaze behavior during visually guided walking?

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A complex array of competing task demands, such as locating a landmark, avoiding obstacles, and regulating foot placement on challenging terrain, necessitate appropriate spatial-temporal gaze behavior and proper gaze-foot coordination when walking. Because of our imperfect knowledge of the world, many environmental features critical to this action are uncertain. For example, we may encounter terrain in which we do not know its characteristics. Here, we determined whether gaze is sensitive to uncertainty to control foot placement. In this experiment, participants (n = 8) walked and stepped on three irregularly spaced targets projected on the floor. To create three different levels of environmental (i.e., target) uncertainty (no, low, and high), we manipulated the standard deviation of two-dimensional Gaussian luminance blobs. We instructed participants to either step onto the centre of these blob targets (High-Accuracy task) or anywhere onto the targets (Low-Accuracy task) in different blocks of trials. We used a motion capture system to track foot placement and a high-speed, head-mounted mobile eye tracker to measure gaze. Our data show that participants spent more time fixating the targets in the High-Accuracy task. More importantly, total fixation time on the targets increased as their uncertainty increased in the High-Accuracy, but not Low-Accuracy task. We also found increased foot-placement error in the Low-Accuracy task overall, and with greater target uncertainty. In contrast, we found similar error among the three uncertainty conditions in the High-Accuracy task. Taken together, our results suggest that people choose to prolong fixation time on specific ground locations to control foot placement while walking. In line with past research (e.g., Gottlieb et al. 2014), we further suggest that this adaptive gaze strategy is due to an intrinsic motivation to reduce uncertainty and increase the expected reward of a future action; in this case, to ensure safe, accurate foot placement.

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36.4065 Choosing actions that maintain sprint ability during repeated target interception tasks

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In many sports and real-world activities that involve repeatedly intercepting moving targets, humans and other animals must be selective about which targets to pursue. Chasing targets that are moving too quickly to catch is futile. Even catchable targets may sometimes be best left to get away if, for example, the energetic costs of interception would leave the actor in a state of exhaustion and unable to pursue the next target. Thus, actors must not only take into account how fast they are capable of moving, but also decide whether pursuit of a target at a particular pace is worth the anticipated energy expenditure and the diminished ability to pursue targets in the future. To investigate how actors take all of these factors into account, we instructed subjects to use a steering wheel and foot pedal to catch cylindrical targets in a virtual environment before they escaped into a forest on the edge of an open field. The objective was to catch as many targets as possible in the time allotted for each block. However, sprinting after every target led to poor performance because the farther subjects depressed the foot pedal, the more quickly they lost energy. This reduced the speed at which they were capable of moving and lengthened the time they needed to rest in order to once again catch faster targets. We found that subjects were more likely to pursue targets when their energy level at the beginning of the trial was higher, revealing that they were sensitive to their changing energy levels on a trial by trial basis. The data also suggest that subjects were able to anticipate how their action capabilities diminished when they chased targets and how this would affect their ability to catch the target on the current trial and in the near future.

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36.4066 Slowed optic flow is used to perceive object motion during active locomotion

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Although locomotion generates complex optic flow patterns across the retina, sighted animals simultaneously perceive their self-motion and the motion of independently moving objects, while retaining a stable percept of the environment. A perceptually stable reference frame could be established by discounting the optic flow component due to self-motion, a mechanism that is consistent with observed underestimation of optic flow speed during open-loop treadmill walking (Thurrell, Pelah & Distler 1998; Thurrell & Pelah 2005; the slowing effect of Pelah, Barbur, Thurrell & Hock 2015). A world-centric reference frame is critically important for perceiving object motion during object interception and other locomotor tasks (Fajen 2013), which may also rely on the discounting of the observer's self-motion to recover the object motion through the world (Warren & Rushton 2009; Layton & Fajen 2016). We investigated whether a common mechanism could account for the world-centric reference frame established during both self-motion and object motion perception. In each trial, subjects either

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walked on a treadmill or remained stationary while viewing a simulated self-motion optic flow display, which contained a moving object that glided along the ground plane towards the observer. Subjects then adjusted, while stationary, the trajectory of an identical object to match the just-perceived (walking or stationary) object trajectory. Results showed that object motion judgments while walking, compared to while stationary, were biased toward the locomotor path. This finding would be expected had subjects experienced the slowing effect, which we confirmed in a separate experiment. We conclude that the visual system may use a slowed version of the global optic flow field, combined with non-visual signals during active locomotion, to recover world-centric object motion. The flow immediately surrounding the object also impacted judgments, which suggests that a local mechanism interacts with the global motion discounting process that occurs to maintain perceptual stability during locomotion.

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36.4067 **Glaucoma-related changes in gaze behavior affect mobility but are modifiable** Shaila Gunn[1](shailag@sfu.ca), Kim Lajoie[1], Andreas Miller[1], Kim Zebehazy[2], Robert Strath[1], David Neima[3], Daniel Marigold[1]; [1]Department of Biomedical Physiology and Kinesiology, Simon Fraser University, Burnaby, British Columbia, Canada, [2]Department of Educational and Counselling Psychology, and Special Education, University of British Columbia, Vancouver, British Columbia, Canada, [3]Private Practice, New Westminster, British Columbia, Canada

Visual field loss associated with glaucoma affects mobility, resulting in slower walking, increased obstacle collisions, and more falls. Glaucoma-related visual loss may disrupt appropriate gaze behavior and gaze-foot coupling, which are necessary for safe route selection and foot placement. We first tested the hypothesis that gaze behavior is different between older adults with glaucoma (n = 10) and normal-sighted controls (n = 10), and that this affects mobility. Subjects performed a precision walking task where they stepped to the center of four irregularly spaced targets under three conditions: targets only, dual search, and dual count. In the targets only condition, subjects only performed the precision walking task. In the dual search condition, subjects had to find and recall the location of one of four shapes along the perimeter of the walkway while performing the precision walking task. In the dual count condition, subjects counted backwards while performing the precision walking task to simulate a conversation. We recorded gaze behavior with a head-mounted mobile eye tracker and foot placement with a motion capture system. In all conditions, the glaucoma group shifted gaze off targets sooner relative to when their heel contacted them; this is associated with a high risk of falling in older adults (Chapman and Hollands, 2006). They also had greater foot-placement error than controls. Subsequently, we developed a gaze training intervention to modify gaze behavior. We taught (2, 1-hr sessions) older adults with glaucoma (n = 2) appropriate scanning and task-specific gaze strategies. To assess its effectiveness, subjects performed the precision walking task before and one week after training. After training, subjects shifted gaze off targets later relative to stepping on them and decreased foot-placement error in all conditions. These preliminary results suggest that gaze is modifiable in older adults with glaucoma, and that gaze training may improve mobility.

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36.4068 **Use of echolocation and long cane for obstacle avoidance during walking: Effects of visual impairment and echolocation expertise** Lore Thaler[1](lore.thaler@durham.ac.uk), Daniel Kish[2], Dorothy Cowie[1]; [1]Department of Psychology, Durham University, UK, [2]World Access for the Blind, USA

Vision loss poses challenges for people's mobility. Previous reports in the literature have found that echo-acoustics can be useful for avoidance of obstacles, but these studies did not dissociate between objects at head and ground level, or considered use of other mobility methods such as long cane in combination with echolocation, or the role played by echolocation expertise. Here we tested a sample of 7 blind echolocation experts, and 14 sighted, and 7 blind people new to echolocation. The task was to use either mouth-click based echolocation, long cane, or both, to avoid an obstacle (60x60cm polystyrene board) that could be either at head or ground level. 3D-movement and sound data were acquired simultaneously using a vicon motion-capture system and head worn microphones. We found that use of echolocation significantly decreased collisions and impact speed with obstacles at head, but not ground level for all participants. This may result from acoustic masking of ground obstacles via floor reflections. In contrast, the cane significantly decreased collisions with obstacles at ground, but not head level. The combined use of echolocation and cane resulted in fewest collisions overall. The main difference between echolocation experts and other participants was that experts had significantly higher walking speeds in all conditions. In fact, walking speed of experts was not significantly different from walking speed of sighted participants using vision. Further analyses suggest that echolocation experts, as compared to people new to echolocation, tended to make more head movements during clicking. These results confirm previous reports showing that echolocation improves mobility for people who are blind. Importantly, they also highlight that care must be taken in instructing potential users due to low efficiency of echolocation for detection of ground obstacles. The results also present a first attempt at characterizing dynamic human echolocation (synchronous sound and movement data)

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36.4069 **How do people steer a car to intercept a moving target: the visual control of locomotor interception** Huaiyong Zhao[1](huaiyong-zhao@126.com), Dominik Straub[1], Constantin Rothkopf[1]; [1]Department of Psychology, Technical University Darmstadt

Three strategies have been proposed for locomotor interception: the pursuit strategy keeps target-heading constant at zero; constant target-heading strategy (CTH) keeps target-heading constant at a certain value; at last, constant bearing strategy (CB) keeps the target at a constant bearing angle relative to an allocentric reference axis. Numerous studies have tested these strategies in tasks where participants controlled only locomotion speed along a fixed straight path. This task constraint makes it impossible for subjects to use the pursuit strategy, and it does not allow discriminating between the CB and the CTH strategies since any change in bearing angle is equivalent to a change in target-heading angle. In two experiments we tested these strategies by asking participants to steer a car to intercept a moving target in three virtual environments: the plant-wall environment included a textured ground plane with some plants and a wall on it, providing richer visual information about allocentric reference including a reference axis; the textured-ground environment included the bare textured ground plane, providing relatively poorer information about allocentric reference; the green-ground environment included only a ground plane of solid green, eliminating any visual information about allocentric reference in the environment. Although steering behavior varied among participants, they all brought target-heading to a constant greater than zero, consistent with the CTH strategy rather than the pursuit strategy. Only very few participants steered a linear interception path with a low rate of turning/steering adjustment and change in target's bearing angle – the sign of the CB strategy. This overall pattern of steering was also observed in the green-ground environment, inconsistent with subjects using an allocentric reference frame to intercept moving targets with the CB strategy. Overall, our results suggest that locomotor interception is better accounted for by the CTH strategy rather than the pursuit strategy or the CB strategy.

36.4070 **Disentangling the contribution of optic flow and perspective cues to the control of walking toward a goal** Li Li[1,2](ll114@nyu.edu), Wei Sun[3], Jing Chen[1], Guangtao Zhai[4]; [1]Neural Science Program, New York University Shanghai, PRC, [2]Department of Psychology, The University of Hong Kong, Pokfulam, Hong Kong SAR, [3]Department of Automation, Shanghai Jiao Tong University, PRC, [4]Department of Electronic Engineering, Shanghai Jiao Tong University, PRC

Previous research reported that both optic flow and target egocentric direction are used for the visual guidance of walking toward a goal. However, the effect of optic flow might be confounded with perspective cues provided by the structure of the environment. Here we disentangled the contribution of optic flow and perspective cues to the control of walking toward a goal. Participants (n=12) wore a head-mounted display (Oculus DK2, FOV: 100°) and walked toward a target placed in four types of virtual environment: (1) a vertical line that provided no optic flow or perspective information, (2) an empty room that provided perspective but no optic flow information, (3) a textured ground that provided optic flow but no perspec-

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tive information, and (4) a textured room that provided both optic flow and perspective information. Participants' walking speed specified by optic flow was 0.5, 1, or 4 times (flow gains) of their physical walking speed. The target was placed in front of participants at 4, 8, or 32m in the virtual world according to the specified flow gain, and participants' virtual heading specified by optic flow was displaced ±10° from their physical walking direction. We found that overall path was straighter and heading error was smaller with than without optic flow. Perspective cues alone affected path curvature and heading error mainly at close distances. Perspective cues had minimal effects on walking in the presence of optic flow. With optic flow, path started to straighten and heading error started to drop earlier with increasing optic flow gain. We conclude that while perspective cues alone contribute to the control of walking at close distances, optic flow is a more powerful cue and diminishes the use of perspective cues. The larger the magnitude of optic flow, the sooner it is used for locomotion control.

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36.4071 **A vision-based model for the joint control of speed and heading in pedestrian following** Gregory Dachner[1](gregory_dachner@brown.edu), William Warren[1]; [1]Brown University

To explain the collective behavior of human crowds, we begin by characterizing the local interactions between individual pedestrians. One such interaction is following, which may lead to coherent crowd motion. In previous work, we found that the follower matches the leader's speed (Rio et al., 2014) and heading direction (Dachner & Warren, 2014), and investigated the visual coupling between them. Dachner & Warren (VSS 2016) proposed that the follower's speed and heading are controlled by nulling the leader's optical expansion and change in bearing direction, depending on their relative positions. Here we attempt to simulate Dachner & Warren's (2016) data using a vision-based dynamical model with only these optical variables as input. 12 participants were instructed to follow a virtual pole (40 cm width), which appeared in three initial positions relative to the participant (0˚, 30˚, 60˚ from straight ahead). Mid-way through a trial, the pole changed its rate of expansion, bearing direction, or both; these optical variables specified a change in the pole's speed, direction, or both. Participants walked freely wearing a head-mounted display, while their head trajectory was recorded. Based on the same visual input, the model outputs a simulated trajectory for each trial. Preliminary results demonstrate a good fit to the participant data. Incorporating visual thresholds for expansion rate and angular velocity from Regan & Hamstra (1998) further improves the model's fit. The results support the hypothesis that, when the pole is in front of the participant, optical expansion controls speed and change in bearing controls heading, while when the pole is to one side, these relations reverse. Models of crowd behavior are typically not based on visual information. A vision-based model more closely simulates following behavior and provides insight into the visual coupling between pedestrians in a crowd. Supported by NSF BCS-1431406 and NIH T32-EY018080-08.

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36.4072 **Recruitment of Pedestrians into Collective Crowd Motion** Trenton Wirth[1](trenton_wirth@brown.edu), William Warren[1]; [1]Brown University

Collective motion in human crowds is thought to emerge from visual interactions between individual pedestrians. A key problem in understanding the formation of collective motion is the conditions under which an individual is recruited into the collective and aligns their heading direction with their neighbors. In previous research, we found that a participant is influenced by a weighted average of visible neighbors, with a weight that decays linearly with distance (Warren & Rio, VSS 2015; Wirth & Warren, VSS 2016). Thus, a greater alignment of neighbors within this neighborhood should have a stronger influence on the participant's heading direction. Participants walked in a 12 by 14 meter tracking space, among a virtual crowd while wearing a wireless Oculus head-mounted display; head trajectory was recorded. A crowd of 24 virtual humans appeared within a 176° horizontal window in front of the participant, evenly distributed in depth from 2.5 to 8.5 meters. During a trial, the crowd walked forward for one second, and then the entire crowd would turn either 10° or 20° to the left or right. Noise was added into individual heading directions, randomly selected from a square distribution with a range of +/- 15°, +/- 30°, or +/- 45° about the common turn angle. The results show that the participants' mean final heading direction was close to 10° and 20°, while the within-subject SD significantly increased with crowd noise ($p< .01$). We plan to simulate these results using the neighborhood model. The findings are consistent with stronger recruitment of individual pedestrians by neighbors who are more aligned.

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36.4073 **Simulating collective motion with a model of pedestrian following** William Warren[1](Bill_Warren@brown.edu), Gregory Dachner[1]; [1]Dept. of Cognitive, Linguistic & Psychological Sciences, Brown University

A bottom-up approach to understanding crowd behavior begins by modeling local interactions between pairs of pedestrians, and then scaling up to simulate the collective motion of crowds. Previously, we developed a dynamical model of pedestrian following, and we now test whether the model can simulate empirical data on collective motion. In earlier experiments, we found that a follower matches the leader's speed (Rio, Rhea, & Warren, 2014) and heading direction (Dachner & Warren, 2014); we also determined that the influence of neighbors in a crowd decreases linearly with distance (Warren & Rio, VSS 2015). Here we test how well the model simulates data previously collected in the Sayles Swarm (Warren & Bonneaud, VSS 2014) on groups of pedestrians walking together. Head position was recorded with 16 motion-capture cameras in a 12m x 20m tracking area. First, we model groups of 4 pedestrians walking 20m (initial interpersonal distance 1, 2, 4 m). On each trial, participants were instructed to turn twice (left-right; right-left; left-left; or right-right) or change speed twice (slow-fast; fast-slow; slow-slow; or fast-fast) as a group, at a self-selected time. Second, we model groups of 20 participants who were instructed to walk about the tracking area for 2 min, veering randomly left and right while staying together as a group (initial interpersonal distance 1, 2 m). We simulate one pedestrian at a time, taking the data from other visible pedestrians as input, and generate a simulated trajectory as output, for each trial. The time series of the pedestrian's speed and heading are compared to those of the simulated agent, with R^2 and RMS error as dependent measures. Initial results demonstrate a good fit to the human data, with fixed parameters. An empirically-based following model thus successfully scales up to simulate the collective motion of pedestrian groups.

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36.4074 **Finding Home: Cue integration and prior knowledge.** Simon Jetzschke[1](sjetzschke@uni-bielefeld.de), Marc Ernst[2], Norbert Boeddeker[1]; [1]Dept. of Cognitive Neuroscience, Biology Faculty, Bielefeld University, [2]Appl. Cognitive Psychology, Faculty for Computer Science, Engineering, and Psychology, Ulm University

Spatial navigation tasks often require us to memorize the relation between visual landmarks and the goal. Landmarks might only provide ambiguous or unreliable cues, making it necessary to make predictions about landmark reliability when learning a new location. These predictions might be enhanced with prior knowledge. How does anticipation about landmark properties affect learning of a spatial location? We studied navigation performance in two different virtual reality homing tasks. The participants walked on a treadmill surrounded by six large flat panel displays and navigated in a simulated desert environment or a parking lot. In both tasks they learned the position of a goal, determined by different landmarks. They were then relocated to a new position and had to return to the previously learned location. In the desert scene we tested how participants integrated ambiguous landmark cues and how conflicting cues change affect performance. In the parking lot scene we tested how participants choose reliable landmarks when locating a position in a cluttered environment that provides many possible landmark cues. The participants integrated the spatial information from each landmark near-optimally to reduce spatial variability. When the conflict becomes big, this integration breaks down and precision is sacrificed for accuracy. A probabilistic model based on the performance with only one ambiguous landmark can predict this integration performance. Participants use prior knowledge about object properties to select presumably reliable objects when they are freely choosing landmarks in the cluttered parking lot scene. Here we find that they use information from their day to day environment in order to avoid navigational errors by unreliable landmarks. How this knowledge is gained and to which extent is it used in increasingly complex scenarios is currently under investigation.

Acknowledgement: Supported by the Cluster of Excellence Cognitive Interaction Technology 'CITEC' (EXC 277) at Bielefeld University

36.4075 **Visual, Vestibular, and Proprioceptive Contributions to Path Integration in a Novel Homing Task** Elizabeth Chrastil[1,2](chrastil@ucsb.edu), Grace Nicora[1]; [1]Department of Geography, University of California Santa Barbara, [2]Program in Dynamical Neuroscience, University of California Santa Barbara

Navigation is a vital part of our daily lives, and it is important to understand the informational inputs that contribute to our sense of orientation. Path integration, the continuous updating of position and orientation during self-motion, relies on several sources of information, including vision, vestibular information, and proprioceptive input from walking. However, the relative contributions of these sources of information have not fully been determined. Homing during path integration has typically been tested using a triangle completion task, in which navigators are guided on two legs of an outbound path and then must generate a trajectory back to the start location, but this task leaves open the potential for execution errors during the homebound trajectory. Here, we introduce a novel path integration task that does not rely on integration of complex turns or execution of a homeward trajectory: the loop closure task. In the loop closure task, participants travel on a loop trajectory and indicate when they think they have traversed one full loop and had returned to the start location. To test the contributions of different sources of information to tracking position, participants completed the loop closure task while a) walking and b) sitting in a wheelchair. Those two levels of idiothetic information were crossed with i) full vision and ii) movement while blindfolded. Visual stimuli consisted of a textured ground plane presented to participants over a head-mounted display, and the experimenter guided the participant along the loop trajectories. The primary outcome measure was the distance between the actual start location of the loop and the location marked by the participant as the start. Preliminary results indicate that the smallest errors were in the walking-vision condition, followed by the walking-blindfold condition, then the two wheelchair conditions. These findings suggest that proprioceptive information is the largest contributor to path integration.

36.4076 **Navigation and pointing errors in non-metric environments.** Alexander Muryy[1](a.muryy@reading.ac.uk), Andrew Glennerster[1]; [1]School of Psychology & Clinical Language Sciences, University of Reading

Schnapp and Warren (VSS 2007 doi:10.1167/7.9.758) showed that observers in a virtual maze could navigate successfully between remembered objects despite the presence of 'wormholes' that took participants from one location to another without the participant noticing and which made it impossible to reconstruct a consistent metric map of the maze. In our experiment, participants in immersive virtual reality had to collect 4 coloured targets in a specified order. Targets were placed in a virtual maze, hidden behind low walls so that the participant had to come close to see and collect them. From the last target, participants had to point in the direction of the other targets. There were 5 repeats with the same target order ('learning' phase) and three repeats with a different target order where the shortest route between pairs of targets was often different from the learned routes. We tested participants in two different maze configurations and for each we tested them with 0, 1 or 3 wormholes. The wormholes increased the length and number of turns between pairs of locations in the maze but did not alter the topological structure. After the learning phase, participants could navigate through the labyrinth efficiently: participants chose the shortest routes in 97% cases for metric scenes, 83% and 75% with 1 and 3 wormholes. However, pointing accuracy was severely affected by the addition of wormholes. The standard deviation of the pointing errors was 13°, 47° and 51° for 0, 1 and 3 wormholes and this spread depended whether the route between a pair of targets was consistent with a metric reconstruction (19°) or not (49°). Participants may not use a single representation for both tasks; at least, the extent of metric information they use depends on the task they are set.

Temporal Processing: Sequences, oscillations and temporal order

Sunday, May 21, 2:45 - 6:45 pm
Poster Session, Pavilion

36.4077 **Temporal and Behavioral Aspects of Subjective Video Quality Perception** Christos Bampis[1](bampis@utexas.edu), Alan Bovik[1]; [1]Department of Electrical and Computer Engineering, The University of Texas at Austin

Streaming video accounts for a large fraction of the overall volume of mobile video data traffic. Because of network and throughput limitations, streaming video data may be afflicted by two dominant impairments: rebuffering events (where the video "freezes" - Fig. 1) and compression artifacts. Given that the end goal of every content provider is to maximize every end-user's visual quality of experience (QoE), subjective modelling of streaming video QoE has become a major concern. We have recently created a database to study the effects of temporal impairments on the behavior of human subjective raters. The new video QoE database contains long video sequences that were QoE-rated by human subjects under mobile viewing conditions, compressed to typical low bitrate values and subjected to realistic network and buffer constraints (Fig. 2). We observed that rebuffering was always obvious and unpleasant to subjects (Fig. 3) while bitrate (compression) changes tended to be less obvious due to content-related dependencies. On more compressible contents, transient bitrate drops (to avoid rebuffering) were preferred over rebuffering events, while consistently low bitrates were poorly tolerated. Further, long playback interruptions on higher quality videos led to larger drops in subjective QoE than on lower quality videos (Fig. 4). We also analyzed long and short term memory effects: when the perceived video quality was relatively stable, recent experiences were more influential (the "recency" effect) while impairments that occured early in a video activated longer term memory reactions (the "primacy" effect) (Fig. 5). We also evaluated a variety of high-performance objective video quality assessment algorithms on the new database and observed that they were unreliable predictors of visual QoE on videos that suffered from both rebuffering events and bitrate changes (Table I). We conclude that more general QoE models are needed that account for distortions, rebuffering events, and memory.

Acknowledgement: Netflix Inc.

36.4078 **Changing Moral Judgments by Exploiting the Visual System** Julian De Freitas[1](defreitas@g.harvard.edu), George Alvarez[1]; [1]Department of Psychology, Harvard University

How does vision interface with the rest of cognition? We showed observers an animation in which the main event was somewhat ambiguous (a red car moves behind a blue car, which then moves and stops next to a pedestrian, who then falls), and asked them to judge who was to blame for the outcome. Below this key event, we showed an irrelevant contextual event (a circle moves and stops next to a second circle, which then moves at the same velocity as the first). People tend to perceive the first circle as causing the second circle to move, and such contextual events have been shown to increase perceived causality in an ambiguous event that occurs simultaneously. Thus, we hypothesized that the contextual event would make participants more likely to see the red car as causing the blue car to move, and therefore blame the driver of the red car for the incident. Indeed, observers were more likely to blame the driver of the red car when there was a causal-contextual event than when there was not, suggesting that causal phenomenology steered their moral judgments (E1). The severity of blame judgments scaled with the contextual event's duration (E2) and temporal asynchrony relative to the car event (E3), and the effects also generalized to a potential boundary condition — a mini car bumps into a huge trash truck — where explicit knowledge might have prevented the effect (observers could reason that a mini is unlikely to cause a huge truck to accelerate to the same speed from rest; E4). Further, only 30% of observers predicted that such contextual events would change their blame judgments about the drivers (E5), indicating that these effects are counterintuitive. Collectively, the findings suggest that causal phenomenology elicited by irrelevant contextual events leaves systematic fingerprints in moral judgment.

36.4079 **Ambient luminance changes modulate oscillatory properties of the visual system**
Alessandro Benedetto[1,2](aml.benedetto@gmail.com), Diego Lozano-Soldevilla[3], Rufin Vanrullen[3,4]; [1]Department of Translational Research on New Technologies in Medicines and Surgery, University of Pisa, Via San Zeno 31, 56123 Pisa, Italy, [2]Department of Neuroscience, Psychology, Pharmacology and Child Health, University of Florence, 50135 Florence, Italy, [3]Institute of Neuroscience, National Research Council (CNR), 56124 Pisa, ItalyCentre National de la Recherche Scientifique (CNRS), Unité Mixte de Recherche 5549, Faculté de Médecine Purpan, Toulouse, France, [4]Centre de Recherche Cerveau et Cognition, Université Paul Sabatier, Toulouse, France

We investigated the effects of ambient luminance changes on neural oscillation dynamics. Brain oscillations, particularly in the alpha range (~10 Hz), are important in determining our percepts. Crucially, ambient luminance changes drastically modulate neural processing. However, the influence of luminance over brain rhythmicity is still not clear. Here, we investigated on 16 subjects the effect of ambient luminance on EEG alpha during spontaneous brain activity at rest (experiment 1) and on 12 subjects during the measurement of the EEG "impulse-response functions" (IRF, or echo function) or the evoked alpha (experiment 2). Results show that during resting, alpha amplitude increased at low luminance ($p < 0.001$), while luminance changes did not affect alpha frequency. In the second experiment, we found that under low-luminance viewing the IRF amplitude was lower ($p < 0.001$), and its frequency was slightly faster ($p < 0.05$). Crucially, the evoked alpha activity behaved differently from the echo function: while evoked alpha and echoes showed a similar amplitude modulation, luminance changes influenced the echo peak frequency but not that of evoked EEG alpha. Finally, we explored the behavioral effects of these modulations in a monocular critical flicker frequency task for 13 subjects (CFF, experiment 3), reporting a facilitatory effect of contralateral dark ambient luminance over temporal thresholds ($p < 0.001$). Globally, we found that ambient luminance changes affect neural oscillatory dynamics and greatly impact on the occipital alpha expression. These results suggest that the visual system adapts its oscillatory dynamics to fit the environmental light conditions.

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36.4080 **Long vs. short integrators: resting state alpha frequency predicts individual differences in temporal integration**
Jan Drewes[1](mail@jandrewes.de), Weina Zhu[1,2], Evelyn Muschter[1], David Melcher[1]; [1]Center for Mind/Brain Sciences (CIMeC), University of Trento, Rovereto, Italy, [2]School of Information Science, Yunnan University, Kunming, China

Temporal integration and segregation are key elements of visual perception. When two visual events happen in rapid succession, they may not be separable to the visual system and are thus processed as one event. With longer temporal intervals between events, the probability for the events to be temporally segregated increases. Given suitable timing, identical paired-stimulus presentations may result in different outcomes (segregation or integration) on a trial-by-trial basis. We presented two flashes of light in rapid succession at different ISIs (33, 66, 100 and 400ms) while recording MEG. The first stimulus was presented at threshold intensity, while the second stimulus was presented at above-threshold intensity. A total of 17 subjects reported the number of stimuli seen (one or two). A baseline condition with only one pulse was included to minimize bias. To better exclude chance guesses from the analysis, the paired flashes were shown randomly in one of four quadrants. Trials in which subjects identified the wrong quadrant were eliminated. Behaviorally, subjects differed in their ability to correctly discriminate the two pulses, with some needing a much longer ISI in order to reliably detect both stimuli. The difference between timing conditions was reflected in the evoked responses to the two stimulus pulses. In addition, we found a significant correlation between the individual duration of the temporal integration window (as indicated by the individual behavioral performance) of our subjects and their measured resting state alpha frequency. These results provide evidence for a close link between the speed at which visual information is integrated or segregated and the resting rate of neural oscillations in the brain, with a possible connection being the individual speed of the underlying neural substrate.

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36.4081 **Alpha oscillation phase determines the timing of perception: evidence from sensory entrainment**
Luca Ronconi[1](luca.ronconi05@gmail.com), David Melcher[1]; [1]Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy

Introduction: While sensory inputs are continuous, perception involves grouping information over time. Recent studies have renewed the idea that the processing of information within different temporal windows is linked to the phase and/or frequency of ongoing oscillatory activity in the alpha band (8-12 Hz). However, being correlational in nature, this evidence might merely reflect a non-functional by-product rather than a causal mechanism. A causal link can be shown with methods that manipulate oscillatory activity, exploiting the tendency of neural oscillations to show entrainment to periodic external forces. Methods: Here, we used audio-visual entrainment at the lower and upper boundaries of the alpha band (i.e. audio-visual rhythmic sequences running at 8.5 vs. 11.5 Hz) in the pre-stimulus period of a temporal integration/segregation task. We hypothesized that entrainment would align ongoing alpha oscillations and drive them towards either a slower or faster frequency. To measure any oscillation in temporal perception as a consequence of the entrainment, we employed a dense-sampling method. We measured the perceptual interpretation of a bistable stimulus, consisting of two brief flashes separated by a brief blank delay that was perceived as either one single flash or two flashes. We densely sampled performance at different time points after the offset of the entrainment, in order to measure any fluctuations in the interpretation of the stimulus. Results: We found a significant phase alignment of the perceptual oscillation across subjects for both entrainment frequencies (8.5 and 11.5 Hz). The two different conditions yielded power spectrums that each peaked near the entrainment frequency, which was confirmed also by a significant fit of a sinusoid to the behavioral oscillation in each condition. Conclusion: This pattern of results provides evidence that the phase of the ongoing neural oscillations is causally linked to the temporal organization of perception.

Acknowledgement: European Research Council (ERC, StG agreement no. 313658 to D.M.)

36.4082 **Behavioral oscillations of criterion and sensitivity synchronized with action**
Huihui Zhang[1](zhanghuihui.cn@gmail.com), David Alais[1]; [1]School of Psychology, The University of Sydney

Voluntary action can synchronize ongoing brain oscillations, triggering rhythmical modulation of visual contrast sensitivity (Benedetto et al., 2016; Tomassini et al., 2015). In this study, we examined whether voluntary action could trigger oscillations of decision criterion as well as sensitivity, and how learning might affect these oscillations. Participants voluntarily pressed a button to start each trial. After variable time lags (0 - 800 ms, sampled every 5 ms), a brief noisy grating was presented at the fovea and participants discriminated its orientation (45° or -45°). A staircase was used to keep grating contrast at threshold level (75% correct response). Participants did two sessions on different days. Using signal detection theory, we calculated participants' sensitivity and criterion over time. To test the existence of oscillations, we fitted first-order Fourier series to the time series of sensitivity and criterion. We also performed Fast Fourier Transforms on these time series. With permutation tests we found alpha oscillations of both sensitivity (8.5 Hz) and criterion (10.5 Hz) that were synchronized with voluntary action. To reveal the influence of learning, we separately analysed the data from the first and second sessions. In the first session, sensitivity and criterion oscillated in the alpha range (10.2 Hz and 10.5 Hz, respectively). However, in the second session, we found no oscillations of criterion and the sensitivity oscillation reduced to 8.3 Hz. In summary, our results showed that action could synchronize oscillations of decision criterion as well as sensitivity, but oscillations of criterion only occurred at the early stage of learning. It may suggest different roles of alpha oscillations: alpha oscillations of sensitivity may reflect rhythmic attentional inhibition, whereas alpha oscillations of criterion may reflect the dynamic prestimulus perceptual expectations, which are susceptible to learning.

36.4083 **Post-cuing falsifies drift diffusion and signal detection theory** Dobromir Rahnev[1](rahnev@psych.gatech.edu), Ji Won Bang[1]; [1]Department of Psychology, Georgia Institute of Technology

How do people make perceptual decisions? One critical issue in answering this question is understanding how stimulus information is combined with non-perceptual information. For example, the perceptual information from a noisy grating can be combined with the non-perceptual experimenter-provided information that left (vs. right) orientation is more likely on a particular trial. This type of combination has been extensively studied via pre-cuing paradigms in which subjects are provided with a predictive cue followed by the stimulus itself. According to modeling work using drift diffusion, the subject incorporates the predictive cue by changing the starting point of accumulation. According to signal detection theory, the subject incorporates the predictive cue by shifting her decision criterion. To test the plausibility of these models, we compared the standard pre-cuing paradigm with a post-cuing design where the predictive cue comes after the stimulus. Surprisingly, post-cuing had a much larger influence on subjects' decision than pre-cuing. This effect was large (criterion shift of 0.46 for pre cues vs. 0.82 for post cues; p = 0.00002) and robust (larger effect for post cues in 25/30 subjects). Further, reverse correlation analyses demonstrated that when subjects were prevented from giving an immediate response, both pre- and post-cuing did not alter the timecourse of stimulus processing. These data falsify the drift diffusion model (which has no proper way of dealing with post cues and predicts timecourse changes for pre cues), as well as both signal detection theory and probabilistic population codes (both of which predict equal criterion shift for pre and post cues). Instead the data are readily explained by a model sensitive to the order of information integration where newer information is given higher weight. This model further accounts for the ubiquitous finding that subjects in pre-cuing paradigms shift their criterion too little and thus fall short of optimality.

Temporal Processing: Timing

Sunday, May 21, 2:45 - 6:45 pm
Poster Session, Pavilion

36.4084 **Comparing the Effects of Implicit and Explicit Temporal Expectation on Choice Response Time and Response Conflict** Melisa Menceloglu[1](mencel@u.northwestern.edu), Marcia Grabowecky[1,2], Satoru Suzuki[1,2]; [1]Department of Psychology, Northwestern University, [2]Interdepartmental Neuroscience Program, Northwestern University

People can use temporally structured sensory information to anticipate future events. Temporal information can be implicitly presented through probability manipulation without participants' awareness of the manipulation, or explicitly conveyed through instructions. We examined how implicit and explicit temporal information established temporal expectations that influenced choice response times and response conflict (measured as flanker effects). We implicitly manipulated temporal structure by block-wise varying the likely timing of a target. In the short-interval block, a target was presented frequently (80% of trials) after a short (400ms) cue-to-target interval and infrequently (20% of trials) after a long (1200ms) interval; the probability assignment was reversed in the long-interval block. Building on this baseline condition (Experiment 1), we augmented the temporal information by filling the cue-to-target intervals with tones (Experiment 2), explicitly informed participants of the prevalent time interval (Experiment 3), and provided trial-by-trial reminders of the prevalent time interval (Experiment 4). The temporal probability manipulation alone (of which participants were unaware) influenced choice response times but only when the temporal information was augmented with tones, whereas providing the explicit knowledge of the temporal manipulation, with or without trial-by-trial reminders, robustly influenced choice response times. Response conflict was unaffected by these conditions. These results suggest that temporal expectation can be established by the implicit learning of a temporal structure given that sufficiently strong temporal information is presented as well as by the explicit knowledge of the temporal structure. This established temporal expectation influences choice response times without necessarily affecting the strength of response conflict.

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36.4085 **Latency-variable time integration mechanisms underlie generalized flash-lag effect** Ryusuke Hayashi[1](r-hayashi@aist.go.jp); [1]Systems Neuroscience Group, AIST

Generalized flash-lag effect (FLE) is a visual phenomenon in which an abrupt onset of flash is typically perceived to lag behind a continuously changing visual feature by several tens of milliseconds. To test whether three previously proposed hypotheses (temporal extrapolation, latency difference and time integration) hold true for other situations than the FLE of motion, I measured the time window for binding the content of three different visual attributes (bar orientation, head orientation of 3D face images, and face identity of morphing face images) to a visual flash or pulse sound (auditory flash) using a reverse correlation technique. In experiments, participants (n=10) were instructed to look at a sequential presentation of randomly-chosen images and report the content at the time when a visual or auditory flash appeared (2AFC task by pressing buttons). Each participant repeated 400 trials for each condition. In case of visual flash, the peak latencies of the estimated time windows were +43ms, -13ms and -84ms for bar orientation, face orientation and face identity, respectively (+ means time after flash and vice versa). Therefore, flash-lead, instead of flash-lag was observed in face identity judge. On the other hand, in case of auditory flash, the peak latencies were +47ms, +74ms and +75ms, showing small difference depending on visual attribute. The half-band width of these time windows was significantly wider for auditory flash than for visual flash. Together with the results from experiments measuring FLE of smoothly changing visual features whose change direction flips in midstream, it is suggested that temporal integration process whose time range changes depending on visual attribute and flash modality underlies the perception of FLE, i.e. a hybrid of latency difference and time integration hypotheses. Our results also indicate different temporal mechanisms between within-modal binding and cross-modal binding.

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36.4086 **Temporal properties of mirror-symmetry perception** Rebecca Sharman[1](rebecca.sharman@stir.ac.uk), Elena Gheorghiu[1]; [1]Department of Psychology, University of Stirling

The human visual system has specialised mechanisms for encoding mirror-symmetry. Recent studies suggest that temporal dynamics rather than symmetrical motion direction contribute to mirror-symmetry perception (Sharman & Gheorghiu (2016), Perception, 45). Here we investigate temporal aspects of symmetry perception by examining how pattern elements are combined over time. Stimuli were dynamic random-dot patterns consisting of an on-going alternation of two images containing different amounts of mirror-symmetry about the vertical axis. We used five different stimulus configurations: 1) a symmetric pattern alternated with a noise pattern; 2) the left and right halves of the symmetric and noise patterns presented with temporal delay (i.e. delayed halves condition); 3) two symmetric patterns alternated over time, with each pattern containing 50% of the [RS1] symmetric matched-pairs; 4) the same as configuration 3, but with matched-pairs presented with temporal delay (i.e. delayed matched-pairs condition); 5) symmetric and noise patterns presented simultaneously as one static pattern. We varied the presentation duration of the two images between 23.5ms and 294ms and the proportion of symmetrical dots. We measured symmetry detection using a 1AFC procedure in which participants indicated whether or not a stimulus was symmetric. Analyses of the slopes of the psychometric functions fitted to the data for each condition showed that symmetry is (a) detected in delayed halves and delayed matched-pairs conditions up to a temporal delay of about 120ms; (b) easily perceived when the symmetric halves or matched-pairs are simultaneously presented, irrespective of the duration of the noise pattern. We conclude that cross-correlation across the symmetry axis can be integrated over time and symmetry mechanisms can tolerate delays of up to about 120ms.

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36.4087 **Apparent motion of a coherent and continuously moving random-dot pattern appears slower in update rate** Teresa Inoue[1](teresa@l.u-tokyo.ac.jp), Ikuya Murakami[1]; [1]The University of Tokyo

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A moving stimulus appears to last longer than a static one (Brown, 1995). This perceptual time expansion depends on temporal statistics of stimuli (Kanai, et al., 2006; Kaneko & Murakami, 2009). Recently, Inoue, Itoi, and Murakami (ICP 2016) reported a related but new time illusion. A random-dot pattern moved coherently in the same direction across multiple frames ("Coh"), moved coherently but in a random direction every frame ("CohRand"), or was refreshed to a new pattern every frame ("Rand"). The frame update rate was 6.7 Hz. Participants matched a train of periodical click sounds to the perceived rate of frame update. It was found that the perceived update rate in the Coh condition was slower than others. The present study attempted to extend this previous report by examining the above illusion over a range of jump sizes between succeeding frames while introducing more stringent controls in stimulus parameters, such as fixation maintenance during each trial, avoidance of optokinetic nystagmus, and setting a focus on the update rate per se rather than the duration. We provided a fixation point throughout each trial and simultaneously presented a moving pattern in one hemifield and its rotation-symmetrical version in the other hemifield to discourage reflexive eye movement. These visual patterns were displayed for an interval shaped by a blurred temporal window and were followed by a train of click sounds. In a two-alternative forced-choice paradigm with the method of constant stimuli, participants reported which one appeared to be updated faster, the visual pattern or click sounds. The results indicated that perceived update rate was slowest in the Coh condition and fastest in the Rand condition. In addition, the shorter the jump size was, the stronger the illusion. The results will be discussed in relation to costs of smooth scene maintenance and abrupt scene update.

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36.4088 **Evoked neural response variability predicts poor timing precision**

Derek Arnold[1](darnold@psy.uq.edu.au), Natasha Mathews[1], Brendan Keane[1], Kielan Yarrow[2]; [1]School of Psychology, The University of Queensland, [2]Department of Psychology, City University London

The neural processes underlying human timing sensitivity, and its variance, remain poorly understood. One possibility is that relative timing is encoded in terms of when signals reach some critical structure(s) in the brain. This possibility, often called 'brain time', remains controversial. According to the brain time hypothesis, variable encoding dynamics from trial to trial should result in variable decisions being made about the timings of identical stimulations, resulting in imprecision. To assess this possibility, we measured the dynamics of audio and visual evoked brain activity, using electroencephalography, to see if these could predict audio-visual timing precision. We found that the precision of an individuals' audio-visual timing decisions could be predicted by the degree of inter-trial variance in their evoked brain activity following identical stimulations. The relevant variance was distinct, detectable from specific sensors, and it did not predict control task performances – judgments of visual pattern frequency or auditory signal origin. These results are consistent with the brain time hypothesis. They are broadly inconsistent with philosophically inspired accounts, which suggest that human timing is shaped by compensatory strategies that counter the influence of brain dynamics.

Acknowledgement: The Australian Research Council

36.4089 **Pre- versus Post-Stimulus Comparison of Correlated Spiking Variability across V1 Laminae**

Jacob Westerberg[1](jacob.a.westerberg@vanderbilt.edu), Michele Cox[1], Kacie Dougherty[1], Alexander Maier[1]; [1]Department of Psychology, College of Arts and Sciences, Vanderbilt University

Correlated spiking between cortical neurons affects sensory coding. Previous work has established that neurons across the layers of visual cortex differ systematically in their spontaneous activity as well as in the degree to which they are correlated across trials in their visual response. However, we know little about how spontaneously occurring spike rate correlations are related to those evoked under visual stimulation. Here we investigate correlated variability within and across the layers of macaque primary visual cortex (V1), and compare their spatial structure during fixation on a neutrally grey screen versus stimulation with high contrast Gabor grating patches of varying orientations. We placed linear multielectrode arrays spanning all layers of V1 in two monkeys that were trained to fixate on a screen while stimuli were presented to the receptive field of neurons under study (n=63 penetrations). Electrodes were aligned and laminar compartments delineated using Current Source Density (CSD) analysis. We extracted multiunit activity as a measure of population spiking within the supragranular, granular and infragranular laminar compartments. Correlated trial-by-trial variability was computed within and across compartments for each stimulus type, and then averaged across all stimulus orientations. We found that spontaneously correlated spiking variability across V1 layers is significantly greater than that obtained from a randomized trial-shuffle control. However, the degree of the spontaneously generated correlated spiking variability varied systematically between layers. Visual stimulation altered spike rate correlations in a layer-specific manner even though spiking increased uniformly across the entire cortical column. Taken together, these findings suggest that the laminar structure of visually evoked correlated spiking variability differs significantly from the spatial structure of spontaneously occurring spike rate correlations. We will discuss these findings in the context of sensory coding within V1's laminar microcircuit.

36.4090 **Human flicker fusion frequencies correlate negatively with cortical VEP magnocellular nonlinearities**

Alyse Brown[1](ac-6brown@students.latrobe.edu.au), Molly Corner[1], David Crewther[2], Sheila Crewther[1]; [1]School of Psychology and Public Health, La Trobe University, [2]Centre for Human Psychopharmacology, Swinburne University of Technology

The temporal speed with which the brain processes visual information has important implications for our ability to attend, process and respond to our environment in real time. However, the mechanisms behind the temporal thresholds in visual perception are poorly understood. Perceptual processing speed is based, in part, on the recovery speeds of the Magnocellular (M) and Parvocellular (P) visual pathways. Here we compared psychophysically determined flicker frequency thresholds with M and P contributions to the nonlinearities generated in electrophysiological recordings over primary visual cortex. Smaller nonlinearities are proposed to be associated with greater neural efficiency in the visual system and the predominant M nonlinearity was predicted to negatively correlate with achromatic flicker frequency threshold. LED driven achromatic sinusoidal flicker fusion frequencies for high (75%) and low (5%) temporal contrasts were compared, using 76 typically developing young adults, with the M and P nonlinearities of the multifocal Visual Evoked Potential (mfVEP), recorded from occipital scalp (Oz). Flicker task performances showed an effect of contrast with the 5% modulation showing a lower mean threshold than the 95% modulation. As predicted, flicker thresholds for high ($r = -.319$, $n=69$, $p < .003$) and low ($r = -.216$, $n=68$, $p < .036$) contrast negatively correlated with the amplitude of the main M nonlinearity (K2.1 [N60-P90]) component, indicating that perceptual speed of processing is linked to more efficient cortical processing. This is the first study to directly correlate a non-linear component of the VEP to a psychophysically measured visual threshold - flicker fusion frequency. Furthermore, this finding should help consolidate the link between primate and human studies by showing that a physiological measure of Magnocellular function based on primate contrast response functions links a putatively Magnocellular response limit to high frequency flicker.

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EYE MOVEMENTS: NEURAL MECHANISMS

Monday, May 22, 8:15 - 9:45 am
Talk Session, Talk Room 1
Moderator: Michele Basso

41.11, *8:15 am* **Modulation of oculomotor control & adaptation with cerebellar TMS: effects on saccades.** Claudia Martin Calderon[1](claudia.alexa.martin@gmail.com), Ian Erkelens[1], Heidi Patterson[1], William Bobier[1], Benjamin Thompson[1,2]; [1]University of Waterloo, School of Optometry & Vision Science, [2]Univesity of Auckland, School of Optometry & Vision Science

The cerebellum plays a significant role in oculomotor control. Previous fMRI, repetitive TMS and lesion studies indicate its involvement in the adaptation of saccadic eye movements in humans. Building on this work, we applied continuous theta-burst (cTBS) TMS to the oculomotor vermis (OMV) of the posterior cerebellum to investigate its specific role in the execution of reactive pro-saccades and their adaptation to a double-step stimulus. 16 healthy controls completed 2 study visits where reactive pro-saccades and their adaptation to a gain reducing double-step stimulus were measured binocularly via infrared oculography at 250Hz. Active or sham cTBS (3-50Hz pulses at 200ms intervals for 40 seconds) was applied to the OMV using a 2x75mm butterfly coil at 80% of the individual's active motor threshold before completing the saccadic tasks at each visit. Stimulation sites were localized using the BrainSight® neuro-navigation system and anatomical landmarks. Compared to sham, active cTBS significantly reduced the adaptation of saccadic gain by 46.8% ($p< 0.0001$). The adaptive reduction of peak velocity after active cTBS was 79.4% less than sham ($p< 0.0001$), while the reduction of saccade duration was 55.2% less ($p=0.009$). Baseline pro-saccade gain was reduced by active (0.97±0.01) vs. sham (0.99±0.009) stimulation ($p = 0.034$). Baseline latency was not different between active (185ms) and sham (181ms) conditions ($p = 0.34$) and was not affected by stimulation type after adaptation (active = +1.2ms, sham = +2.5ms, $p>0.50$). These results demonstrate the central role of the OMV in the feed-forward control and feed-back driven adaptation of reactive pro-saccades, consistent with previous work. In addition, the results are the first to clearly establish the robust inhibitory effects of cTBS on oculomotor control and adaptation when applied to the OMV of the posterior cerebellum.

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41.12, *8:30 am* **EEG decoding of pre-saccadic effects on post-saccadic processing** Grace Edwards[1,2](gcaedwards1@gmail.com), Rufin VanRullen[1], Patrick Cavanagh[2,3]; [1]Centre de Recherche Cerveau & Cognition, Toulouse, France, [2]Laboratoire Psychologie de la Perception, Paris, France, [3]Psychological and Brain Sciences, Dartmouth College, USA

Using electroencephalography (EEG) and multivariate pattern analysis (MVPA) we examined whether saccade target information affects post-saccadic target processing. Subjects were instructed to saccade toward a face or a house that, on different trials, could remain the same, change, or disappear during the saccade. We used MVPA to decode between face and house stimuli in the post-saccadic period. The classifier was trained on a separate set of trials without a saccade, where a house or face was presented at the fovea. When the saccade target remained the same during the saccade, we were able to decode the target 154 ms after saccade onset ($p< 0.05$ FDR corrected). In contrast, when the saccade target was changed during the saccade, the new target was decoded at a later time-point, 190 ms after saccade onset ($p< 0.05$ FDR corrected). The 36 ms advantage for the "same" condition suggests that pre-saccadic information facilitated the processing of the post-saccadic stimulus. Finally, the saccade target could be decoded at 235 ms when it had been removed during the saccade ($p< 0.05$ FDR corrected). This result may be a neural correlate of the previously reported "ghost" illusion (Wolf et al. 1980) whereby subjects report briefly seeing the saccade target even though it is no longer present when saccade lands. The late classification may indicate that this illusory percept has a long time course with lower signal strength that reaches recognition threshold later than the physically present stimuli. These findings indicate that information about the (peripheral) pre-saccadic stimulus is transferred across the saccade so that it becomes available and influences processing at a new retinal position (the fovea) when the saccade has landed.

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41.13, *8:45 am* **Functional and structural organization of the foveal visual representation of the primate superior colliculus** Chih-Yang Chen[1,2](chen.chih-yang@cin.uni-tuebingen.de), Claudia Distler[3], Klaus-Peter Hoffmann[4], Ziad Hafed[2]; [1]Graduate School of Neural and Behavioural Sciences, International Max Planck Research School, Osterbergstrasse 3, Tuebingen, 72074 GERMANY , [2]Werner Reichardt Centre for Integrative Neuroscience, Otfried-Muller Strasse 25, Tuebingen, 72076 GERMANY, [3]Department of General Zoology and Neurobiology, Ruhr-University Bochum, Universitätsstr. 150, Bochum, 44780, GERMANY, [4]Faculty of Biology and Biotechnology, Ruhr-University Bochum, Universitätsstr. 150, Bochum, 44780, GERMANY

A primary reason for using non-human primates in visual neuroscience is their foveated retina. However, neurophysiological investigations of foveal representations are not common because of difficulties with eye movements and small response fields (RF's). This creates a pressing need to study foveal representations, especially given that foveal processing is the mode of operation that we rely on most heavily in our daily life. Here we recorded from the foveal visual representation of the superior colliculus (SC) in 2 awake and 3 anesthetized monkeys. In the awake animals, we recorded from 70 neurons with preferred eccentricities < 1 deg and compared their visual RF characteristics to those of >100 more eccentric neurons. We corrected for eye position during fixation to obtain better estimates of RF shapes and sizes. In the anesthetized animals, we densely mapped preferred RF locations and related them to SC anatomy. We systematically moved our electrodes by 100, 250, or 500 micrometer steps in both rostral-caudal and medial-lateral axes. We found that foveal SC neurons' RF's were strongly skewed and lateralized, having sharp cutoffs at the "foveal edge" of the visual representation. RF skew decreased progressively with eccentricity, along with an exponential increase in RF size. Our dense mappings also revealed very orderly foveal representation topography, which is continuous with the well-known peripheral SC topography. We used our mappings to develop a 3-D model of the topographic foveal SC representation. Our results demonstrate strong laterality of visual representations in the foveal SC, and fairly large magnification of foveal space in SC tissue, even larger than that used in current models of SC topography. The magnification and continuity of foveal topography at this level of detail have implications on the potential impacts of small eye movements on visual coding, and might also explain certain characteristics of microsaccade amplitude distributions.

41.14, *9:00 am* **Superior colliculus coordinates pupillary and saccadic responses** CHIN-AN WANG[1](josh.wang@queensu.ca), Douglas Munoz[1]; [1]Centre for Neuroscience Studies, Queen's University

The appearance of a salient stimulus in the environment evokes a series of responses to orient the body for appropriate action. These responses include eye movements and pupil dilation that may be coordinated by the midbrain superior colliculus (SC). The role of the SC on saccade and pupil dilation has been separately established, but whether these responses are linked is still unknown. Here, we investigated the coordination between saccadic and pupillary responses through microstimulation of the SC with manipulating stimulation parameters and background luminance. Parameters of SC microstimulation are known to systematically modulate properties of evoked saccades. If the orienting responses are coordinated by the SC, the similar modulation should be observed in pupil size by varying stimulation train frequency and duration (frequency: 150-300 Hz; stimulation train duration: 25-100 ms). While requiring monkeys to maintain central fixation, we stimulated the intermediate SC layers. Varying

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train frequency and duration systematically modulated saccadic as well as pupillary responses. Importantly, the positive trial-by-trial correlation between two responses was observed within individual stimulation condition. Trials with larger saccadic responses had larger pupillary responses, and larger pupil responses were observed on trials with evoked saccades, compared to trials without evoked saccades. These results together suggest that the same output signals from the intermediate SC project to both pupil and saccade premotor circuits to initiate coordinated responses. Background luminance influenced pupillary but not saccadic responses, characterizing the pupil-specific modulation. Together, our results demonstrate coordinated orienting movements of saccade and pupil size through the SC, importantly extending an integrated role of the SC among various orienting movements.

41.15, *9:15 am* **Investigating Perceptual Confidence in the Superior Colliculus with Multi-Unit Neuronal Recordings** Brian Odegaard[1](odegaard.brian@gmail.com), Piercesare Grimaldi[2], Seong Cho[3], Megan Peters[1], Hakwan Lau[1], Michele Basso[4]; [1]Department of Psychology, UCLA, [2]Department of Psychiatry, UCLA, [3]Department of Integrative Biology and Physiology, UCLA, [4]Departments of Psychiatry, Biobehavioral Sciences, and Neurobiology, UCLA

Our subjective visual experience of the world comes with varying degrees of confidence in the things we see. Previous research indicates that different brain regions may facilitate our capacity for confidence, such as the lateral intraparietal area (Kiani & Shadlen, 2009), supplementary eye fields (Middlebrooks & Sommer, 2012), and pulvinar (Komura et al., 2013). Here, we investigated whether another part of the oculomotor control circuit, the superior colliculus (SC), also plays a role, and developed a novel task to investigate whether population-level activity in the SC reflects perceptual confidence, or simply predicts perceptual performance. Two rhesus macaques viewed random dot motion stimuli and reported the perceived direction of motion with eye movements. If monkeys chose correctly, they received a reward. On half of the trials, monkeys received an opt-out target option, which could be selected to receive a smaller but guaranteed reward; this choice is taken to reflect low subjective confidence. We first implemented logistic regression classification to determine if we could predict correct perceptual choices from neuronal activity in the SC. We found that decoding accuracy was greater on trials when the opt-out was available but waived, presumably reflecting high confidence. Critically, in our new task, we manipulated dot motion coherences to produce two conditions that had equivalent levels of performance (d') but different levels of confidence (i.e., probability of selecting the opt-out response). Results indicate that once performance is matched, population-level activity does not differ between high and low confidence conditions. These results support the hypothesis that SC activity primarily predicts perceptual performance rather than subjective confidence per se, and highlight an important methodological innovation for future investigations of perceptual confidence in other brain regions.

41.16, *9:30 am* **Dissociating contributions of visual working memory and saccade preparation in V4 activity** Donatas Jonikaitis[1,2](djonikaitis@googlemail.com), Tirin Moore[1,2]; [1]Neurobiology, Stanford University, [2]Howard Hughes Medical Institute, Stanford University

Visual spatial working memory and oculomotor control are processes thought to be highly interdependent and brought about by similar neural mechanisms. In humans and non-human primates visual cortex is known to show modulation during tasks requiring oculomotor selection. Further, human imaging studies demonstrate that in the absence of visual information, visual memory delay activity is observed in visual cortex. However, working memory representations, as measured by spiking activity in early visual cortex are largely absent. By adding an irrelevant background texture pattern to the display in order to evoke visual responses from neurons, we were able to unmask modulations in visual activity during memory task. During the task, while the monkey fixated a central spot, a briefly flashed peripheral visual cue indicated a location to be remembered. After a delay period, two stimuli appeared, one at the memorized location, and one at a new location. The monkey was rewarded for saccades either to the stimulus at the memorized location ('Look' blocks) or to the other location ('Avoid' blocks). Importantly, in both types of blocks, the monkey was required to remember the cue location, yet only in the 'Look' blocks could it prepare a saccade to that location. In the 'Avoid' blocks, saccade preparation was eliminated, as indicated by slow saccadic reaction times. During the task, we recorded from neurons in area V4 using linear array microelectrodes and measured their responses during the delay period. We observed clear working memory responses in neural receptive fields during trials on which the memory cue appeared in the neuronal receptive field compared to trials on which the cue appeared elsewhere. Further, memory responses were observed during 'Avoid' blocks, ruling out saccadic preparation as a cause for observed effects. We conclude that memory activity in visual area V4 can be observed independent of saccade preparation.

PERCEPTUAL ORGANIZATION

Monday, May 22, 8:15 - 9:45 am
Talk Session, Talk Room 2
Moderator: Shin'ya Nishida

41.21, *8:15 am* **Spatial configuration modulates perceptual transparency from dymamic image deformation** Takahiro Kawabe[1](kawabe.takahiro@lab.ntt.co.jp), Shin'ya Nishida[1]; [1]NTT Communication Science Laboratories, Nippon Telegraph and Telephone Corporation, Japan

A recent study has proved that dynamic image deformation can contribute to perceptual transparency (Kawabe, Maruya, & Nishida, 2015, PNAS). It is well known that spatial configuration cues such as contour junctions regulates traditional phenomenal transparency. The present study reports that such spatial configuration is also a critical factor to modulate perceptual transparency from dynamic image deformation. Our stimulus image contained the arrays of ring-like objects. The image was vertically divided into three regions consisting of a central deforming region in which the ring-like objects were dynamically deformed with a fixed spatiotemporal frequency, and two peripheral undeforming regions wherein the objects were presented intact. When both deforming and undeforming regions were presented, the observers reported the strong impression of a transparent layer. On the other hand, the impression was significantly attenuated when only a central deforming region was presented. We also found that the spatial continuity of object contours between the deforming and undeforming regions played a critical role in seeing the transparent layer; hindering the continuity reduced the impression. Finally, when the contrast polarity of objects was modulated so that the traditional perceptual transparency was weakened, the impression of a transparent layer from image deformation was also weakened albeit under the existence of peripheral undeforming regions. Taken together, our results suggest that perceptual transparency from image deformation is enhanced by spatial configuration of stimuli when the configuration provides the evidence that spatial structure of a continuous scene/object is modulated by an intervention of a transparent material. In addition, the results that perceptual transparency from luminance contour junction influenced the interpretation of perceptual transparency from image deformation suggest that interaction between two sorts of perceptual transparency takes place at some levels of visual processing.

Acknowledgement: This work was supported by JSPS KAKENHI Grant Number JP15H05915.

41.22, *8:30 am* **Spontaneous perception of numerosity in humans** David Burr[1,2](dave@in.cnr.it), Guido Cicchini[2], Giovanni Anobile[3]; [1]Department of Neuroscience, University of Florence, Italy, [2]CNR Institute of Neuroscience, Pisa, Italy, [3]Stella Maris Foundation, Pisa, Italy

Introduction: Humans and many other species can make rapid, nonverbal estimates of numerosity. However, it is still unclear whether numerosity is detected spontaneously by dedicated mechanisms, or calculated indirectly via texture-density mechanisms. Methods: We used an "odd-one-out" technique to measure the equivalent of "MacAdam Ellipses" in a two-dimensional logarithmic "numerosity space", defined by density and area (with numerosity given by the positive diagonal in the space). Results: For stimuli of moderate densities, discriminations were well described by an elongated ellipse, with the short axis (maximum sensitivity) aligned to the numerosity diagonal. Sensitivity along this axis was 16 times that of the orthogonal direction, showing that numerosity is the most sensitive dimension, and can not be predicted from the independent thresholds for area and density. We also measured discrimination ellipses with a subjective technique, where subjects were asked to make explicit judgments about numeros-

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ity, density or area. Psychometric functions for number judgments were aligned to the numerosity direction (45°), but those for area and density judgments were not aligned to their axes (0 and 90°), but strongly biased towards number. This suggests that area and density judgments may be at least partially mediated by numerosity mechanisms, rather than the other way round. At high densities, where items were too crowded to be perceptually segregated, the discrimination ellipses became more circular, and are well predicted by independent encoding of area and density. Discussion: The results clearly point to the existence of mechanisms selectively encoding numerosity. The clear differences in processing of sparse and dense arrays shows that these specialized numerosity mechanisms operate only under conditions where the items can be perceptually segregated.

41.23, *8:45 am* **Choice-induced biases in visually perceived numerosity** Long Luu[1](longluu@sas.upenn.edu), Alan Stocker[1]; [1]Department of Psychology, University of Pennsylvania

Making a categorical decision can systematically bias our subsequent perception of a stimulus. We have previously shown that these biases are well predicted by an observer model that maintains self-consistency across a sequential assessment of the same sensory evidence (Luu/Stocker, VSS 2015). However, experimental evidence so far has been limited to low-level visual stimuli such as motion direction (Jazayeri/Movshon 2007, Zamboni et al. 2016) or local visual orientation (Luu/Stocker, VSS 2015). Thus it was unknown whether self-consistent behavior generalizes to tasks involving high-level, more abstract visual stimuli. To answer this question, we conducted a set of psychophysical experiments probing visually perceived numerosity. The main experiments consisted of the following sequential decision-estimation task: In each trial, subjects (N=4) were briefly presented with an array of white dots of various size (diameter: 0.07-0.35 degs) shown on gray background within a circular aperture (7 degs). The number of dots was chosen with equal probability to be anywhere between 33 and 47. After stimulus presentation, subjects first had to report whether the number of dots was larger or smaller than 40. Subsequently, they then also had to provide an actual estimate of the number of dots. In order to modulate stimulus uncertainty, we tested two stimulus conditions that differed in presentation time (either 0.02 s or 1 s). We found the same characteristic biases in subjects' estimates of the number of dots as in the previously reported experiments using low-level visual stimuli. The biases are well accounted for by the self-consistent observer model, outperforming alternative models. Our results suggest that self-consistency may play a fundamental and general role in sequential decision-making tasks.

41.24, *9:00 am* **The role of uncertainty in perceptual organization** Yanli Zhou[1,2](yz1349@nyu.edu), Luigi Acerbi[1], Wei Ji Ma[1,2]; [1]Center for Neural Science, New York University, [2]Department of Psychology, New York University

Perceptual organization is the process of grouping scene elements into whole entities, for example line segments into contours. Previous studies have reframed classic Gestalt principles of perceptual organization in terms of Bayesian models, in which the observer computes the probability that a whole entity is present in the scene. These studies, however, leave open the possibility that people apply a fixed, learned stimulus-response mapping that only mimics Bayesian inference, instead of actually computing with probability distributions. Proper probabilistic computation requires people to flexibly take sensory uncertainty into account even when it varies from trial to trial. Here, we vary uncertainty from trial to trial to distinguish between probabilistic and non-probabilistic inference in a simple form of perceptual organization. Subjects (n = 8) judged whether two line segments separated by an occluder were collinear. In this task, an optimal observer would be probabilistic and utilize knowledge of uncertainty when deciding whether a measured offset between the line segments is due to non-collinearity or to sensory noise. We compare this model against an alternative model that applies a fixed, uncertainty-independent decision boundary. Finally, motivated by a nonparametric examination of the data, we also test a probabilistic heuristic model whose decision boundary is linear in eccentricity. The fixed-boundary model fits by far the worst (leave-one-out cross-validation score, fixed - optimal = -25.5 ± 13.6, fixed - heuristic = -82.8 ± 15.2; mean ± SEM across subjects), providing evidence for probabilistic computation. Moreover, we find that the heuristic model performs better than the optimal model (leave-one-out score, heuristic - optimal = 57.3 ± 10.5), suggesting that people take uncertainty into account in a suboptimal way. The model comparison did not change qualitatively when we estimated parameters from an independent discrimination task. Our work opens the door to investigating the role of uncertainty in more natural forms of perceptual organization.

41.25, *9:15 am* **The topographic representation of global object perception in human visual cortex** Susanne Stoll[1,2](stollsus@gmail.com), Nonie Finlayson[3], D. Samuel Schwarzkopf[3,4]; [1]Philosophische Fakultät II, Humboldt-Universität zu Berlin, [2]Berlin School of Mind and Brain, Humboldt-Universität zu Berlin, [3]Experimental Psychology, University College London, [4]Institute of Cognitive Neuroscience, University College London

Our visual system readily groups dynamic fragmented input into meaningful objects. Yet, how the brain represents such perceptual grouping remains unclear. Here we therefore used fMRI techniques to explore the precise topographic profile of brain activity underlying the perception of two bistable stimuli, each composed of an array of dynamic elements: the translating diamond (Lorenceau & Shiffrar, 1992) and the spinners (Anstis & Kim, 2011). When perceived globally, these stimuli appear as shape objects translating along a single motion path; when perceived locally, they appear as separate elements translating along individual motion paths. In two experiments, we measured brain activity while healthy observers viewed these stimuli and reported their percepts. Additionally, we estimated the population receptive field (pRF) for each voxel in visual cortex (Dumoulin & Wandell, 2008) and used these to back-project the brain activity during stimulus perception into visual space. We observed a large-scale reduction of V1 activity to the global state of either of these stimuli compared to the respective local one. This was accompanied by a general increase of activity in higher object-sensitive cortex—a pattern closely replicating previous work involving similar stimuli. Strikingly, whereas V1 deactivation was particularly prominent along the horizontal meridian for the translating diamond, the peak of V1 deactivation was confined to the center of the stimulus display for the spinners. These signatures roughly corresponded to the motion paths of the inferred shapes during the global percept, indicating they could serve as a label signaling a moving grouped entity. Our findings suggest a possibly crucial computational role of V1 during perceptual grouping of dynamic fragmented input and demonstrate that pRF-based back-projection techniques can potentially reveal hitherto undetected neural signatures of visual perception.

Acknowledgement: This work was supported by an ERC Starting Grant to DSS.

41.26, *9:30 am* **Distinct effects of boundary detection and figure enhancement in the early visual cortex** Sonia Poltoratski[1,2](sonia.poltoratski@vanderbilt.edu), Frank Tong[1,2]; [1]Vanderbilt University Department of Psychology, [2]Vanderbilt Vision Research Center

When an orientation difference defines a region as a distinct 'figure' from its surround, V1 responses to the region increase. Is this enhancement driven by a release from local feature-tuned suppression at the boundary between the target region and surrounding background, or the result of a more widespread figure enhancement? Here, we used fMRI at 7T to resolve the spatial extent of figure-ground modulation in the early human visual system. We measured responses to a central 4° annulus of bandpass-filtered oriented noise embedded in an oriented surround while manipulating the phase alignment and orientation of the surround relative to the center, as well as whether the surround directly abutted the center. To control for effects of covert attention, the observers' focus was directed away from the figure by a task at fixation. In the same session, we mapped population receptive fields (pRF), allowing us to deduce the visual field location to which each voxel responds. We could thus isolate voxels that responded specifically to the central figure, the surround, or to the boundary between them. Results in V1 revealed distinct effects of boundary detection and figure enhancement. Voxels with pRFs encompassing the boundary showed elevated responses, even when the target and surround were iso-oriented and differed only in their spatial phase. When the center and surround were orthogonally oriented, we observed an additional effect of figural enhancement throughout the target representation in V1, even in V1 voxels that received no direct stimulation from the surround. A similar trend of figure enhancement was observed in the lateral geniculate nucleus (LGN). Our results indicate robust figure-ground modulation in early visual system, and clarify the spatial extent of these effects.

Acknowledgement: National Institutes of Health (Grant P30-EY008126) center grant to the Vanderbilt Vision Research Center.

ATTENTION: MOSTLY TEMPORAL

Monday, May 22, 10:45 - 12:15 pm
Talk Session, Talk Room 1
Moderator: Karla Evans

42.11, *10:45 am* **Predicting Scanpath Agreement during Scene Viewing using Deep Neural Networks** Zijun Wei[1](zijwei@cs.stonybrook.edu), Hossein Adeli[2], Minh Hoai[1], Gregory Zelinsky[1,2], Dimitris Samaras[1]; [1]Department of Computer Science, Stony Brook University, [2]Department of Psychology, Stony Brook University

Eye movements are a widely used measure of overt shifts of attention, but this measure is often limited by poor agreement in peoples' gaze, which can vary significantly in the context of free viewing. In this work we ask whether the level of scanpath agreement among participants during scene viewing, quantified using a modified version of the MultiMatch method (Dewhurst et al., 2012), can be predicted using a Deep Neural Network (DNN). Specifically, using image features extracted from the last convolutional layer of a DNN trained for object recognition, we found a linear weighting such that positive regressor weights indicated the presence of image features resulting in greater gaze agreement among viewers. Image regions corresponding to these features were then found by back-propagating the features to the image space using the probabilistic Selective Tuning Attention model (Zhang et al., 2016, ECCV). Combining these regions from all positively weighted features yielded an activation map reflecting the image features important for predicting scanpath consistency among people freely viewing scenes. The model was trained on a randomly selected 80% of the MIT1003 dataset (Judd et al., 2009) and tested on the remaining 20%, repeated 10 times. We found that this linear regressor model was able to predict for each image the level of agreement in the viewers' scanpaths ($r = 0.3$, $p < .01$). Consistent with previous findings, in qualitative analyses we also found that the features of text, faces, and bodies were especially important in predicting gaze agreement. This work introduces a novel method for predicting scanpath agreement, and for identifying the underlying image features important for creating agreement in collective viewing behavior. Future work will extend this approach to identify features of a target goal that are important for producing uniformly strong attentional guidance in the context of visual search tasks.

Acknowledgement: This work was supported by NSF grant IIS-1161876 to D.S. and G.J.Z.

42.12, *11:00 am* **The Implicit Adaptation to Temporal Regularities** Nir Shalev[1](nir.shalev@wolfson.ox.ac.uk), Nele Demeyere[1], Anna Nobre[1,2]; [1]Department of Experimental Psychology, University of Oxford, Oxford, United Kingdom, [2]Oxford Centre for Human Brain Activity, University of Oxford, Oxford, United Kingdom

Our environment often contains useful information about temporal regularities: whether it is a traffic light changing, or the elevator reaching its destination. In the presence of such regularities, we form temporal expectations to anticipate and prepare for relevant events. In the lack of such information, we are required to sustain higher levels of vigilance to respond to unpredictable events. In the current study, we combined behavioural and pupillometry measures to investigate the cognitive mechanisms for adapting to implicit temporal regularities in a Continuous Performing Task designed to measure Sustained Attention. Individuals detected occasional targets embedded in an ongoing stimulus stream with different levels of temporal predictability of stimulus onsets in different task epochs. The results revealed evidence for preparatory behaviour in the presence of temporal regularities, reflected in phasic changes in pupil diameter preceding stimulus onset. The magnitude of rapid pupillometry changes also predicted the response type on each trial. In epochs where intervals were randomised, the overall mean pupil size was significantly larger compared to other epochs. We believe this adjustment reflects an adaptive process relying on the coeruleus–noradrenergic system in regulating task engagement when uncertainty is increased. Our findings provide evidence for cognitive adaptation in response to different levels of temporal regularities. Individuals increase their alertness when targets are unpredictable, and prepare for their appearance when they are predictable. These observations enhance our understanding of the underlying processes of variations in performance over time, by revealing dynamic shifts in cognitive modes in response to varying uncertainty.

Acknowledgement: European Union FP7 Marie Curie ITN Grant (606901)

42.13, *11:15 am* **Is Onset King? Comparing Attention Capture Effects for Onset and Looming Stimuli** Joanna Lewis[1](joanna.lewis@knights.ucf.edu), Mark Neider[1]; [1]Psychology, College of Sciences, University of Central Florida

Onset type stimuli have been shown to capture attention in conditions where other singletons fail to do so, such as when the attentional set is not adjusted to monitoring for onsets. As such, onsets have been considered to be uniquely robust in capturing attention. However, looming stimuli have been shown to similarly capture attention, possibly because both are dynamic stimuli that represent some need for behavioral urgency. In our experiments, participants completed a visual search task for a target oval among spheres and made an orientation judgement (set size 4 or 6). One object (target or distractor) either loomed or onset. Singleton type was blocked. Looming was generated via apparent motion, followed by the target replacing a distractor sphere after motion was completed. The onset singleton occurred when the target array was displayed. In Experiment 1, we found a response time cost between distractor and target singletons, reflecting attention capture. Additionally, participants were faster responding to looming targets and slower for looming distractors compared to similar onset stimuli. To account for onset effects possibly being related to the simultaneous presentation of the onset and the target display, in Experiment 2 we examined only onsets at 3 temporal delays (60, 120, 200ms). We found higher response time differences for onsets occurring earlier in the sequence, suggesting that the strongest test between the stimulus types would be onsets occurring prior to the target onset, which we tested in Experiment 3. We found participants were faster responding to looming targets and slower in responding to looming distractors at the highest set size only. These results suggest onsets may be just one type of a small group of stimuli possessing strong attentional capture signals. Future work will examine the influence of attentional set to determine if these dynamic singletons are comparable in capturing attention.

Acknowledgement: NSF GRFP

42.14, *11:30 am* **Multiple object tracking doesn't care if you are crossing the street or bouncing off the walls** Farahnaz Wick[1,2](farahnaz@gmail.com), Jeremy Wolfe[1,2]; [1]Brigham and Women's Hospital, [2]Harvard Medical School

In our dynamic world, it is important to be able to track items over space and time. The multiple object tracking task has been used to investigate the ability to sustain attention on multiple identical items undergoing random motion. Our abilities in such tasks are very limited. When tracking has been studied in the lab, performance declines rapidly if you track more than three or four objects. Typically, motion tracking displays have used random motion with, perhaps, some rules of physics governing collisions. In the real world, however, we are likely to be more interested in tracking items that are subject to effects of crowding and social factors such as "personal space". Might our tracking capacity be greater for stimuli closer to what we need to track? We created motion tracking displays using the social force model for pedestrian dynamics (Helbing, 1995). Items behaved like pedestrians crossing intersections or walking along the sidewalk. We varied the number of items, using larger set sizes than typical (20, 30 and 40 objects). In separate experiments, we measured tracking accuracy with social force motion, social force motion played backwards, random motion with social force interactions, and more traditional random motion with either overlaps or elastic collisions between objects. The number of targets varied between 4-10 objects and the tracking time was 10 seconds. At the end of 10 seconds, observers reported the tracked targets using mouse clicks and were given feedback. Tracking capacity was calculated using Pashler's K. Capacity was quite high, especially considering the visual set size. But the capacity declined as set size (and crowding) increased down to the usual 3 or 4 items for all types of motion. Social force rules did not improve tracking capacity, suggesting that the constraints on tracking may occur relatively early in motion processing.

Acknowledgement: Army Research Office W911NF-15-2-0046

 SEE PAGE 3 FOR ABSTRACT NUMBERING SYSTEM

42.15, *11:45 am* **Allocation of Attention in a Complex Environment**
Karla Evans[1](karla.evans@york.ac.uk), Lucy Spencer[1]; [1]Department of Psychology, The University of York, UK

Visual attention is a set of control mechanisms that adapt the visual system for completion of different perceptual tasks, allowing us to perceive our complex environment. There are two prominent views on how allocation of this resource affords us the ability to individuate and recognize an object in a complex scene, and also register global properties of the same scene. One view sees this as workings of one single process whose activity ranges from narrowly focused analysis of local binding of features, to global registration of image and summary statistics (Tresiman, 2006). The opposing view argues that it is a result of two processes (one selective and one non-selective), but does not make a prediction of whether they work in parallel or not (Wolfe et al., 2011). Does perception operate along a continuum of one process, or using two processes in serial or in parallel? We used a dual-task paradigm to test these three possible models, in which a task requiring global processing is performed simultaneously with another task requiring the same, or with a task requiring focused processing. Observers completed three single-task conditions (image categorization, average global dot movement, and central single dot movement). The difficulty on the two dot tasks were equated. This was followed by two dual-task conditions, one of which used two global tasks (image categorization and average global dot movement), the other of which used both a global and a focused task (image categorization with single dot motion direction). We compared the observers' performance while they performed two tasks simultaneously to their performance on single-task conditions. The results are in favour of a single process with both global and single dot tasks showing the same degree of reduction in accuracy during dual tasks, but with no reduction in image categorization accuracy.

42.16, *12:00 pm* **Perceptual and attentional factors in detection of driving-relevant visual events**
Ruth Rosenholtz[1,2](rruth@mit.edu), Benjamin Wolfe[2,3], Ben Sawyer[3], Anna Kosovicheva[4], Bryan Reimer[3]; [1]Dept. of Brain & Cognitive Sciences, MIT, [2]CSAIL, MIT, [3]AgeLab, MIT, [4]Dept. of Psychology, Northeastern University

Driving often involves multitasking, whether texting, viewing directions on the navigation system, or simply checking the rearview mirrors while maintaining lane position and monitoring the roadway for hazards. Multitasking, in turn, typically involves not only attending away from the forward roadway, but also looking away. Dual task human vision experiments have attempted to separate the factors of attentional limits and fixation, but little work has been done to extend this methodology to stimuli and tasks of relevance to driving. It is not immediately obvious that dual task results with artificial displays and often-semantic tasks generalize to cluttered natural scenes and navigation-related tasks. We asked subjects (n=30, 15 female) to watch forward-facing road video recorded around Boston, MA, and report brake light events in their lane of travel. We manipulated cognitive load by asking subjects to perform one of two secondary tasks at fixation (easy vs. hard), while independently enforcing fixation at one of 4 locations (center of video, corresponding to forward roadway, as well as 30º left, 30º right and 20º down from center). We found that looking away from the forward roadway significantly reduced brake light detection performance (-8%, $p < 0.001$), increased response time (+350 ms, $p < 0.001$), and, most dangerously in a driving context, dramatically increased the number of missed brake light events (+15%, $p < 0.001$), although differences between non-central locations were not significant. Increasing cognitive load, however, had a smaller effect, with no significant changes in performance, though trends towards increased miss rates, relative to the low cognitive load condition (+5%, p=.207), and decreased detection performance (-3%, p=.371), respectively. Drivers can detect many salient events using peripheral vision, but looking away comes with severe penalties.

Acknowledgement: Toyota Research Institute grant to RR

Binocular Vision: Stereopsis

Monday, May 22, 10:45 - 12:15 pm
Talk Session, Talk Room 2
Moderator: Paul Hibbard

42.21, *10:45 am* **Modeling response variability in disparity-selective cells**
Sid Henriksen[1](s.henriksen@ncl.ac.uk), Bruce Cumming[2], Jenny Read[1]; [1]Institute of Neuroscience, Newcastle University, UK, [2]Laboratory of Sensorimotor Research, National Institutes of Health, US

Stereo vision relies on disparity-selective cells in primary visual cortex. The binocular energy model (BEM) has been successful in capturing a range of properties of these neurons. While the BEM's ability to capture mean rates have received substantial attention, little effort has been directed to understanding response variability. We have previously shown that the BEM predicts that the spike rate variance should increase with the square of the mean rate. Importantly, this variance is stimulus driven, reflecting the effect of different dot patterns while disparity is fixed. Recording from V1 neurons in the macaque, we used a two-pass method to separate stochastic variability ("internal variance") from stimulus induced variability ("external variance"). We found that V1 neurons show much less external variance than the BEM. This failure is partly due to the BEM's highly constrained structure. We fit more general linear-nonlinear (LN) models, with the number of subunits as a free parameter, to neuronal data. This general architecture is able to capture both the mean and variability of real cells much better. In particular, by incorporating multiple orthogonal excitatory subunits, the new model is able to achieve lower variability for a given mean than is possible in the BEM. However, problems remain. Notably, while the BEM produced too much variability, the new model produces too little. We show that while the new model captures the "internal" variability due to the spike generation process, it underestimates the "external" variability produced by different random noise patterns with a given correlation and disparity. The new model also still shows the characteristic relationship between the Fano Factor (Variance/Mean) and the mean which we reported previously in the BEM, and which is absent in real cells. Thus, this substantial generalization of the BEM is still not an accurate model of real V1 neurons

Acknowledgement: SH was funded by an NIH-Wellcome Trust 4 year PhD studentship

42.22, *11:00 am* **Optimized computation of binocular disparity by populations of simple and complex cells**
Nuno Goncalves[1], Andrew Welchman[1]; [1]Department of Psychology, University of Cambridge

Binocular disparities convey unique information about the depth structure of the environment. The process of capturing disparity by V1 neurons is typically described using the disparity energy model (Ohzawa et al., 1990). While this is convenient and elegant in its simplicity, the canonical model does not account for a number of neurophysiological observations. Principally it is not adapted to the statistics of natural disparities, and it fails to exhibit attenuation for binocularly anticorrelated stimuli. Here we develop a model system to test the optimization processes that might underlie neuronal encoding schemes. We used an unbiased modelling approach, optimizing a neural network to extract binocular disparity from naturalistic images. We then compared the properties of model's units with neurophysiological data. We found that a simple feed-forward neural network reproduces key aspects of V1 binocular neurons. First, simple units develop receptive fields with hybrid position and phase disparities, resembling the structure of V1 simple cells. We show that this scheme is adopted as it maximizes the Shannon Information about the depth of the scene. Second, complex units respond selectively to disparity in random-dot stereograms (RDS), without being trained on them. This selectivity extended to anticorrelated RDS, mimicking, very closely, the inverted and attenuated tuning curves found in many V1 complex cells. Using a stimulus optimization method, we show that complex units are maximally activated by position disparities, despite receiving activity from units that exploit phase encoding. Finally, we show that the encoding and readout mechanisms can be captured in simple analytical form, to produce model estimates that approximate the likelihood function for binocular disparity. These results provide a mechanistic and interpretive account of disparity processing in primates, and make a number of predictions for perceptual performance.

42.23, *11:15 am* **Optimal Combination of Disparity across a log Polar Scaled Visual Field**
Guido Maiello[1,2,3](guido_maiello@yahoo.it), Manuela Chessa[2], Fabio Solari[2], Peter Bex[3]; [1]UCL Institute of Ophthalmology, University College London, London, UK., [2]Department of

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Psychology, Northeastern University, Boston, MA, USA., [3]Department of Informatics, Bioengineering, Robotics and System Engineering, University of Genoa, Genoa, Italy.

The human visual system is foveated and the spatial resolution of processing decreases with eccentricity. Sensitivity to stereoscopic disparity varies with spatial frequency and is band-pass tuned in the central visual field. Here, we assess the contributions of different regions of the visual field to disparity processing at different spatial scales. Observers were shown pink noise stereograms, which contained tilted (45° or 135°) sinusoidal corrugations at different modulation spatial frequencies. The corrugation filled a central 21° circular region, or was confined to annular regions spanning 0°-3°, 3°-9° or 9°-21°. Observers indicated the orientation of the corrugation. As expected, disparity sensitivity was band-pass tuned for spatial frequency and the peak shifted to lower spatial frequencies in the peripheral visual field. The envelope of disparity sensitivity for the full field stimulus was the optimal combination of sensitivities across the annular regions. We employed these data to tune and evaluate a foveated log-polar model of disparity processing that mimics the processing stages occurring in primary visual cortex. The model is based on a similar approach we previously developed for the processing of optic flow information directly in the cortical domain [Chessa et al, 2016]. We thus provide a map of disparity sensitivity throughout the visual field and across spatial frequencies, and a biologically plausible model that provides evidence for which neural processing stages are responsible for the topography of disparity sensitivity in man. The common computations of optic flow and stereo disparity in a log polar architecture could be combined to investigate the neural basis of the perception of motion in depth.

Acknowledgement: NIH grant R01EY021553

42.24, *11:30 am* **Latent Binocular Interactions in Cortical Area V1 of Human Amblyopia** Chuan Hou[1](chuanhou@ski.org), Terence Tyson[1], Ismet Üner[1], Preeti Verghese[1]; [1]The Smith-Kettlewell Eye Research Institute

Binocular interaction in amblyopia is typically reported as being absent or greatly reduced. However, Baker et al, (2007) showed intact binocular summation by increasing stimulus contrast to the amblyopic eye in strabismic amblyopia. Here we used fMRI-informed EEG source imaging to measure latent binocular capacity in primary visual cortex (V1) by varying contrast in the amblyopic eye while keeping contrast fixed in the fellow eye. We made measurements in both anisometropic and strabismic amblyopes and compared their data to age-matched normal vision controls. We measured high-density steady-state VEP responses to two parallel grating stimuli (11° diameter, 2 cpd, sine-reversal) with different temporal frequencies presented dichoptically to the two eyes. The contrast in the amblyopic eye (F1=6.07Hz) was either swept from 1% to 40%, or fixed for a block of trials (at 40%, 20%, 10% or 0%, respectively), while the contrast of the fellow eye (F2=8.25Hz) was always fixed at 20%. The presence of intermodulation (IM) frequencies, which are sums and differences of the frequencies presented to the two eyes, was taken as evidence of binocular interaction. In the fixed-contrast condition, both ansiometropic and strabismic amblyopes showed the largest IM responses in V1 when the contrast in the amblyopic eye was 40% and contrast in the fellow was 20%. In the swept-contrast condition, the IM contrast-response function in V1 of anisometropic amblyopes was shifted to higher contrast levels, compared to normal controls. Strabismic amblyopes had significantly reduced IM responses, and only individuals with residual binocular fusion showed a weak IM response at high contrast in the amblyopic eye. Consistent with Baker et al. (2007), we demonstrate evidence for binocular interactions in early visual cortex in some, but not all, types of amblyopia. This finding suggests that amblyopes with residual fusion have the potential to recover deficits in binocularity.

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42.25, *11:45 am* **Human white matter structural properties correlate with individual difference in stereoacuity** Hiroki Oishi[1,2](elanvital0014@gmail.com), Hiromasa Takemura[1,2,3], Shuntaro Aoki[2], Ichiro Fujita[1,2], Kaoru Amano[1,2]; [1]Center for Information and Neural Networks (CiNet), National Institute of Information and Communications Technology, and Osaka University, Suita, Japan, [2]Graduate School of Frontier Biosciences, Osaka University, Suita, Japan, [3]Japan Society for the Promotion of Science, Tokyo, Japan

Humans have substantial individual differences in the performance to identify binocular disparity (stereoacuity; Hess et al, 2016), but its neuroanatomical basis remains unknown. Given that both dorsal and ventral visual cortices process binocular disparity (Parker, 2007; Murphy et al., 2016), one candidate is a white matter tract connecting dorsal and ventral visual areas (Vertical Occipital Fasciculus, VOF; Yeatman et al., 2014; Takemura et al., 2016). Here we tested how the structural property of the VOF is related to the individual difference in stereoacuity by combining structural MRI and psychophysics. We collected diffusion-weighted MRI (dMRI; 2 mm isotropic, 64 directions) and quantitative MRI data (1 mm isotropic) from 19 participants with normal or corrected-to-normal vision (age 20-37, mean: 25.1 years old). After we identified the VOF in each subject using probabilistic tractography (Yeatman et al., 2014), we evaluated its structural properties using Fractional Anisotropy (FA) and Macromolecular Tissue Volume (MTV) measurements that quantify neural tissue density (Mezer et al., 2013). In psychophysics, we presented random-dot stereogram composed of central disk (disparity was varied from±0.002 deg to±0.128 deg) and surrounding annulus (zero disparity). Subjects are asked to judge whether the center disk was nearer or farther than the surrounding annulus. Based on the results of the psychophysical experiment, we classified subjects into higher (N=10) or lower (N=9) stereoacuity groups. We found that higher stereoacuity group showed significantly higher FA values, along the dorsal segment of the right VOF (d'=1.0). We also observed an inter-group difference in MTV along the whole right VOF (d'=0.88). We did not observe a significant difference in other tracts in visual cortex (e.g. optic radiation, forceps major). This result suggests that structural properties of white matter tract involved in dorsal-ventral communications are related to individual difference in stereoacuity.

Acknowledgement: Grand support: JSPS Grant-in-aid for JSPS Fellows to H.T.

42.26, *12:00 pm* **Task-dependent modulation of BOLD responses reveals distinct roles of dorsal and ventral pathways in stereoscopic depth perception** Mizuki Fujita[1,2](m.fujita@fbs.osaka-u.ac.jp), Shuntaro Aoki[1,2], Hiroshi Ban[1,2], Kaoru Amano[1,2], Ichiro Fujita[1,2]; [1]Center for Information and Neural Networks (CiNet), National Institute of Information and Communications Technology, and Osaka University, Suita, Japan, [2]Graduate School of Frontier Biosciences, Osaka University, Suita, Japan

A fundamental challenge of the primate visual system is to reconstruct 3D visual scenes from 2D retinal inputs. Binocular disparity, a slight positional displacement between the left and right retinal images, is one of the powerful cues for depth perception. Numerous physiological and neuroimaging studies have accumulated evidence of distinct roles of dorsal and ventral visual pathways for the processing of binocular disparities. These studies, however, led to inconsistent conclusions in some aspects. This may be partially because these studies used different visual stimuli triggering different activation in visual areas. For instance, some studies used dynamic random-dot stereograms (RDSs), which evoke stronger BOLD responses in dorsal pathway regions. Others used 3D object images, which evoke preferential activation in ventral pathway regions. To eliminate these stimulus effects, we asked observers to perform two distinct depth-discrimination tasks for exactly the same binocular disparity stimuli during fMRI measurements (3T, 1.5 mm isotropic voxels). Specifically, observers were asked to discriminate either position-in-depth of an entire stimulus (a position-in-depth task) or depth of the inner annulus relative to the outer (a 3D shape task), and then we examined how BOLD responses were modulated depending on the task demands in visual areas. We found that dorsal areas including hMT+, VIPS, POIPS, and DIPS showed stronger responses in the position-in-depth task than in the 3D shape task. In contrast, Brodmann's area 39 in the angular gyrus and 21 in the middle temporal gyrus were more engaged in the 3D shape task. Early retinotopic visual areas showed no difference in activation between the two tasks. We suggest that task-dependent (not stimulus-driven) multiple depth processing resides in higher-order dorsal and ventral areas. These results also shed new light on the consistency and inconsistency in the previous findings between monkeys and humans regarding the roles of dorsal and ventral pathways.

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Color and Light: Material Perception

Monday, May 22, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

43.3001 Visually predicting the future states of pouring liquids

Roland Fleming[1](roland.w.fleming@psychol.uni-giessen.de), Jan Jaap Van Assen[1], Filipp Schmidt[1]; [1]Department of Psychology, Justus-Liebig-University Giessen

The way liquids move and change shape is governed by complex physical laws. Despite this, we usually have vivid visual expectations about how liquids ooze or splash, taking into account their viscosity, velocity and surrounding objects. This ability to predict fluids' future states potentially involves both perceptual processes and mental simulation. Bates, Yildirim, Tenenbaum and Battaglia (2015) used observers' predictions about the future locations of liquids to argue for an "intuitive physics engine" based on mental simulation. Here, we focus on predicting the future shapes of liquids, suggesting that robust perceptual feature identification also plays an important role. We simulated 10sec animations of liquids pouring onto a plane. The optical properties were held constant, but viscosity varied (from water to honey) in seven steps. For each liquid, we created eight variations using random wind-like perturbations near the source, which caused the liquids to adopt distinct shapes as they [Jv1] poured. On each trial, observers viewed a 2sec clip from the beginning of one simulation ('test'), along with eight static frames ('matches') taken from a later time point, one for each variant with the same viscosity as the test. Their task was to rank the match stimuli according to how plausibly they could be future states of the test stimulus. Viscosity and the time offset between test and match stimuli varied across trials. Performance declined with time offset but was far above chance in all conditions. Lower viscosities were somewhat easier than higher viscosities. Analysis of the underlying geometry of the liquids revealed that sophisticated feature correspondence processes are required to predict perceived matches. Together our findings suggest the visual system uses robust feature identification with internal models of liquid-related shape changes to predict the future states of liquids.

Acknowledgement: This research was supported by the DFG (SFB-TRR-135: "Cardinal Mechanisms of Perception"), an ERC Consolidator Award (ERC-2015-CoG-682859: "SHAPE") and a Google Faculty Research Award.

43.3002 Viscosity constancy across contexts

Jan Jaap van Assen[1](mail@janjaap.info), Roland Fleming[1]; [1]Department of Psychology, Justus-Liebig-University Giessen

Liquids like water, syrup and tar are highly mutable. Intrinsic properties (e.g. viscosity) and external forces (e.g. object interactions, gravity) cause liquids to adopt a wide range of different shapes depending on the context. Previous work has shown we can predict perceived viscosity in a given scene (e.g., pouring onto a plane) very well through a weighted combination of mid-level shape features (e.g. clumping, spiralling, spread) describing the behaviour of the liquid in that scene. However, one problem such models face is that they do not generalise well to novel scenes (e.g. a liquid being stirred). Because the available shape features are highly context dependent, the visual system must somehow select the most relevant and discriminative features in each specific situation. Here, we investigated the selection process through which the visual system determines which features to use for inferring viscosity in each scene. We simulated liquids with seven different viscosities, interacting with eight different test scenes (e.g. stirring, smearing, raining). Each animated scene (10 seconds) had its own unique interactions with the liquid, yielding a wide range of shapes. In experiment 1, observers matched the viscosity in each test scene by adjusting the liquid in a standard match scene (64 viscosity steps, pouring liquids). In experiment 2, observers rated viscosity in the different scenes. In experiment 3, observers rated 20 different shape features for each scene and viscosity. We find that observers show good overall constancy across scenes, with small but systematic over- and underestimations for certain scenes. By comparing these results to those from the shape feature ratings, we identified which features were visually most influential for each individual scene. The results indicate the visual system flexibly re-weights mid-level cues on a scene-by-scene basis to achieve high levels of constancy.

Acknowledgement: EU FP7 Marie Curie Initial Training Networks (ITN) project PRISM, Perceptual Representation of Illumination, Shape and Material (PITN-GA-2012-316746), DFG: SFB-TRR-135

43.3003 Shatter and splatter: The contribution of motion and surface optics to the perception of non-rigid materials

Alexandra Schmid[1](Alexandra.Schmid@psychol.uni-giessen.de), Katja Doerschner[1]; [1]Justus-Liebig University

Static and motion optical cues have been independently shown to contribute to the appearance of material properties. The influence of mechanical information (through shape or motion cues) is less explored. We conducted experiments to investigate the contributions of, and interactions between, optical, motion, and shape information to material perception. We created novel animations of materials ranging from soft to hard bodies that broke apart differently when dropped. In Experiment 1, animations were rendered as point-light movies varying in dot density, and "full-cue" optical versions ranging from translucent glossy to opaque matte under a natural illumination field. Observers used a scale to rate each substance on 30 different attributes. In Experiment 2 we investigated the contribution of shape to attribute ratings in Experiment 1, by comparing ratings when observers were shown one frame of the animation after the point of impact versus a short movie clip around the point of impact. The results showed: (1) Strikingly, there were interactions between surface optics and substance (hard/soft bodies) for many ratings, which differed when substances were presented in motion compared to static images. (2) Perceived differences between hard and soft bodies were often significantly more pronounced for full-cue stimuli versus both point-light and static stimuli. (3) For some ratings, the motion in the full-cue stimuli overrode information provided by optics in the static images. (4) A factor analysis verified that ratings of the 30 attributes were tapping into a few underlying dimensions, which reflect the manipulated mechanical and optical material properties. Together, the results showed that neither motion nor optics/shape information alone could fully account for the results in the full-cue condition. Therefore, combining motion and optical properties appears to provide additional information about material qualities. These novel findings demonstrate a critical interaction between motion and surface optics in the perception of materials.

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43.3004 Perceiving shape of thin translucent objects from spatial transmittance variation

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While human monocular 3D shape perception has traditionally been investigated using opaque objects, we frequently encounter objects with translucent material properties in our daily life. We can perceive the shape of thin translucent objects such as silk curtains and plastic bags, but the underlying visual processing remains poorly understood. The present study explored what image cues can be used to estimate the shape of translucent sheet-like objects. Consider a corrugated translucent surface with a certain degree of thickness like a veil. The light transmittance of the sheet is expected to be higher when the surface normal is toward a direction of the eye than when it is slanted with regard to the eye direction. This implies that the light transmittance of a translucent sheet can be a shape cue to estimate the surface orientation. In a psychophysical experiment we investigated whether the visual system utilized this cue. The stimulus in the experiment was synthesized by alpha-blending a natural texture with a corrugated CG sheet whose geometric structure was known. There were three transmittance conditions. Consistent condition: the light transmittance (i.e., alpha value) spatially co-varied with the slant of the CG surface. Inconsistent condition: the transmittance map was rotated 90 degrees to break the consis-

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tency. Uniform condition: the transmittance was spatially uniform. In the experiment, we estimated the perceived shape of the translucent sheet by asking observers to set a gauge probe with the apparent surface slant/tilt. Results of the experiment showed that when the transmittance of the blending was consistent with the surface slant, the perceived shape was closer to the ground truth than those under the other two conditions. The finding suggests that the spatial transmittance variation consistent with shading is an effective shape cue of translucent sheets.

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43.3005 Multiple cues for visual perception of mirror and glass materials

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The visual system can easily distinguish between a "mirror" object, which has a perfect specular surface like a polished metal, and a "glass" object, which has a transparent and refraction medium like ice under natural illumination, although an observer just observes a complex distorted image on the object surfaces from the surrounding illumination. In order to identify the visual cues to distinguish mirror and glass materials, we investigated a relationship between observers' performances and static/dynamic cues in visual stimulus.. Three randomly-bumped (potato-shape) objects were modeled by Blender 2.77 and were rendered as mirror and glass material objects by Mitsuba renderer (Jacob, 2010) under five real-world illuminations (Debevec, 2000; Adams et al., 2016). To examine both static and dynamic effects, we presented the static objects as image or the horizontally rotating objects as a video. The observer's task was to identify its material (mirror or glass) in a 2AFC paradigm. In this result, we found that a luminance distribution along a vertical direction in the image was significantly correlated with the performance in the static condition, and a ratio between positive and negative values of motion components along the object rotating direction in the video was significantly correlated with the performance in the dynamic condition. Moreover, for the stimuli color, which inverted from positive to negative values, the observers relatively more depended on a dynamic cue. This result can be caused by a decrease of a reliability of the static cue by the color inversion. These results suggest that the visual system effectively and comprehensively uses multiple cues in order to distinguish several materials in various contexts.

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43.3006 Probing perceptual gloss space with physical surfaces

Joachim Kildau[1](Joachim.Kildau@psychol.uni-giessen.de), Eugen Prokott[1], Roland Fleming[1]; [1]Allgemeine Psychologie, Justus-Liebig-Universität Gießen

Manufactured glossy surfaces can exhibit a wide range of appearance characteristics including haze, sheen, sparkle and goniochromaticity. Specifying, communicating, and controlling the appearance of glossy surfaces remains a challenge for industry as current measurement standards fail to capture the full range of appearances reliably. As a first step towards developing an industrial standard for glossy appearance, we probed perceptual gloss space using a set of 29 curved samples from the lacquer company "Lechler", which spanned a wide range of different appearances. Participants viewed the samples on a matte black background under a 6500K diffuse "White Screen" lamp and performed three tasks. All 32 participants first arranged the samples on the table according to their similarity, with multiple repetitions to organize the samples according to different aspects of their appearance, in descending order of the subjective saliency of the different characteristics. A camera and custom computer vision system recorded the spatial arrangements. Subsequently, 16 participants rated each surface for 22 verbally defined appearance characteristics (e.g., 'metallic', 'coated', 'iridescent', 'dark', 'smooth') using continuous sliders. The other 16 participants performed pair-wise similarity judgments for 16 of the samples. Perceptual distance matrices were derived from all three tasks and analysed using MDS. We also applied PCA to co-registered images of the samples under the same illuminant, to identify image cues associated with the perceptual similarities. We find a striking similarity in the arrangements from different subjects and tasks, which correlated surprisingly well with low-level image measurements derived the image analysis. This suggests a robust and systematic perceptual gloss space, at least when lighting and shape is standardized. The subjective dimensions were arranged hierarchically in 5 - 6 clusters, suggesting that a low-dimensional perceptual space captures most salient aspects of glossy appearance.

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43.3007 Visual estimation of surface BRDF

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The bi-directional reflectance distribution function (BRDF) is a representation used in radiometry to describe the spectral and directional reflectance properties of an opaque surface. BRDF features such as the diffuse and specular reflection are associated with surface appearance properties such as color and gloss. In practice BRDF data are often approximated with light reflection models. For example the Ward model characterizes the BRDF in terms of three parameters, ρd, the diffuse reflectance of the surface, ρs, the specular reflectance of the surface, and α, the standard deviation of the surface slope. Recent advances in our understanding of material perception have benefitted greatly from the use of computer graphics methods that can render photorealistic images from BRDF models, but acquiring BRDF model parameters for real surfaces has been difficult due to the complexity and cost of the goniospectrophotometers required to measure surface BRDFs. In this project we present a method for visually estimating the Ward model parameters of real-world surfaces using a smartphone. We estimate ρd by scaling and linearizing the RGB values extracted from an image of the surface. We estimate ρs by applying the Fresnel equation. Finally, we estimate α by displaying a square wave grating on the smartphone screen, reflecting the grating in the surface under consideration, and adjusting the spatial frequency of the grating until it is just visible. An algorithm that incorporates display characteristics, human contrast sensitivity, and viewing geometry allows us to estimate α from the grating spatial frequency at threshold. We validate of the method by measuring real surfaces, simulating the surfaces using parameters estimated through the method, and comparing images of the real and simulated surfaces.

43.3008 Relationship between perceptual surface qualities and distinctive features in onomatopoetic expression

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We associate shapes and sounds with the psychological concept such as the impression (e.g. size and sharpness). This effect is known as Bouba-Kiki effect (Ramachandran & Hubbard, 2001). Similarly, this sound symbolic effect associates perceptual qualities in vision or haptics and phonemes in Japanese onomatopoeia (Hamano, 1998; Watanabe, et al., 2011). Japanese onomatopoeia has a large vocabulary and is able to express a subtle difference in our material perception. Here, we investigated that the relationship between perceptual surface qualities (e.g. "glossiness", "roughness", "naturalness", etc.) and distinctive features of Japanese onomatopoeia (e.g. "voiced", "continuant", "nasal", "plosive", etc.). 1946 images were used as stimuli selected and trimmed from the Flickr Material Database (Sharan et al., 2014). Observers viewed an image on the calibrated LCD display and rated the surface quality for the given images using 14 adjective pairs based on previous studies (Fleming et al., 2013; Nagai et al., 2015). Moreover, observers described its image impression in Japanese onomatopoeias. We analyzed the correlation between ratings for the 14 surface quality scales and 11 distinctive features (Jakobson et al., 1951) converted from the Japanese onomatopoeias. As a result, surface qualities such as glossiness, roughness, hardness, were highly correlated with distinctive features such as continuant, voiced, affricative. In contrast, other surface qualities such as viscosity, luxury, and naturalness showed less or no correlation with any distinctive features. This result suggests that basic surface qualities like glossiness or roughness are linked to sounds of the onomatopoeias in a similar way as in Bouba-kiki effect, implying that there might exist universality in the relationship between material perception and distinctive features regardless of the linguistic background.

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Color and Light: Lightness and brightness

Monday, May 22, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

43.3009 How to kill the simultaneous lightness contrast illusion

Cristhian Altamirano[1](cristhia@scarletmail.rutgers.edu), Christina Zambrano-Varghese[1], Alan Gilchrist[1]; [1]Rutgers-University Newark Department of Psychology

Anchoring theory claims that simultaneous lightness contrast occurs because the gray target on the black background is the highest luminance in its local framework. Maniatis (2015) challenged this account merely by placing an additional white square on the black background and showing that the illusion is not eliminated. Clearly if the black background were replaced by white, there would be no illusion. Such a white background would differ from the white square Maniatis added in at least three ways: The white background (1) is larger in area, (2) surrounds the target, and (3) shares a border with the target. To determine which property (or combination) might kill the illusion, we created 5 stimulus displays that varied in these properties. Each was viewed on a computer monitor by a separate group of 15 observers who made matches both using a Munsell chart and by adjusting a variable square patch in a checkerboard background on the same computer screen. Surrounding the target with white (without increasing its area) did not reduce the illusion, even though 100% of the target border was in contact with white. Making half of the target overlap the white square reduced the illusion by about half. Only one display killed the illusion: the added white square was enlarged to fill much of the black background but made no contact with the target. This implies that in order to fully anchor the gray target on the black background (thus killing the illusion), the white region must have a sufficient relative area. This is consistent with several publications (Gilchrist & Radonjic, 2009) showing that anchoring depends on both relative luminance and relative area. Our results provide absolutely no support for the traditional lateral inhibition explanation of this illusion.

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43.3010 Visual signals increase faster than the contrasts that elicit them

Joshua Solomon[1](J.A.Solomon@city.ac.uk), Michael Morgan[1]; [1]Applied Vision Research Centre, City, University of London

Modulations in the contrast of dynamic visual noise are invisible above a critical fusion frequency (CFF) of ~15 Hz. Nonetheless, early nonlinearities in the visual system could make low-frequency changes in the amplitude of these modulations appear as changes in intensity. In a method-of-adjustment paradigm, our observers minimized these changes in apparent intensity by manipulating the relative average physical intensities of dynamic noise with large and small amplitudes of modulation. For minimum apparent changes in intensity, observers required relatively less average (root-mean-squared) contrast and relatively more average power (mean squared contrast) when modulation amplitude was large. These results are most consistent with a power-function nonlinearity with an exponent between 1 and 2.

Acknowledgement: Leverhulme Trust #RPG-2016-124

43.3011 When Does Surface Appearance Become Scale-Variant?

Jihyun Yeonan-Kim[1](jihyun.kim@upf.edu), Marcelo Bertalmío[1]; [1]Department of Information and Communication Technologies, Universitat Pompeu Fabra

Surface appearance (brightness and color) of an object in the scene depends on the properties of the surfaces surrounding the object (spatial induction). Size of the surrounding is one of the important influential properties. For example, a larger surrounding induces stronger contrast to the object than a smaller surrounding. Then would size-scaling of the scene alter the appearance? This question arises by acknowledging that scaling the entire scene changes the size of both the surrounding and the object, shifting the overall spatial frequency (SF) spectrum. We studied whether the appearance of a simple spatial induction display differs from its size-scaled version, when and why. We used a bar grating stimuli in which one half of the stimulus is comprised of grey bars alternating with lighter-than-grey bars and the other half with the same grey bars alternating with darker-than-grey bars (as in Helson, 1963). The grey bars on the two sides thus appeared different due to contrast (grey bars in lighter bars appears darker than those in the darker bars; for low SF gratings) or assimilation (grey in lighter appears lighter; for high SF gratings) induced by the inducing bars. The stimulus appearance in a certain size was compared with the identical stimulus in a different scale while contrast of the inducing bars (i.e. relative intensity of the inducing bars to the grey) and the grating SF varied. The appearance was altered for low contrast inducers for a relatively broad SF range, while, for high contrast inducers, there was no clear evidence of the scaling effect except for at the very high SF range. We explain these results in respect of the mutual induction between the inducing and the grey bars, discuss a potential neural mechanism, and compare the results with previous studies on the surrounding-size-dependent spatial induction and contrast constancy.

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43.3012 Brightness reduction in parafoveal stimuli in the simultaneous presence of light inside the natural blind spot

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The natural blind spot (BS) in the visual field has been known as a region, where our visual system cannot receive any optical input. The BS corresponds to the optic disk on the retina where ganglion-cell axons converge and leave the eye as the optic nerve and no rod/cone photoreceptors exist. Therefore, we cannot register any visual signals if they are presented inside the BS focally. Recently, we found that the light illuminating inside the BS enhances pupillary light reflex (PLR), even though it cannot trigger PLR by itself (Miyamoto and Murakami, 2015), suggesting possible existence of a physiological mechanism that receives light inside the BS, or more specifically, melanopsin expressed along the axons of ipRGCs in the optic disk. However, it is unknown if the light illuminating the BS, which contributes to PLR, also affects our visual perception. Here, we addressed this question by visual psychophysics on brightness matching. Two white stimuli, each of which covered a part of the right or left visual hemifield (eccentricity: 5–10 deg), were sequentially presented briefly (duration 50 ms; SOA 150 ms). Participants were requested to judge if the second stimulus (test) was brighter than the first one (reference) by 2AFC. In half of the trials, the test stimulus was accompanied by a bluish oval presented inside the BS, and its effects on the luminance of the test stimulus at the point of subjective equality (PSE) were examined. We found that the test stimulus was judged as darker ($t(7) = 3.48$, $p = 0.010$) with the oval inside the BS than without it. Moreover, there was a slight indication that the oval inside the BS led to PLR enhancement, just as in the previous study. These findings suggest contributions of some physiological photo-sensitive mechanism inside the optic disk to our image-forming vision.

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43.3013 EEG-based classification of images as HDR versus non-HDR using Steady-State Visual Evoked Potential

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Recently, high dynamic range (HDR) images and HDR-ready displays have become available. Compared to the conventional standard dynamic range (SDR) images, HDR images have higher peak luminance and contrast, which leads to more faithful reproduction of actual scenes. Although subjective assessment methods such as the mean opinion score are often applied in order to classify captured or processed images as HDR or non-HDR, results based on these methods are biased by raters' experience and expertise. To address this issue, research on image-quality assessment using electroencephalography is widely performed. Here we determined whether SSVEPs can be to classify test images into HDR or non-HDR content. In this study SSVEPs for seven subjects were recorded during the presentation of five test stimuli. The stimuli consisted of HDR, SDR, and blended images of the HDR and the SDR images. Each SDR image was processed so that its average luminance was identical to the corresponding HDR image. They were presented on a professional HDR monitor at the frequency of 3 Hz. In

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addition, 5-scale mean opinion scores were collected for the stimuli before or after the EEG recordings. The results showed that the response amplitudes of the SSVEPs at the stimulus frequency were highly correlated to the mean opinion scores for most of the stimuli. We also constructed an HDR/non-HDR classification model based on a support vector machine (SVM) with a non-linear kernel. In the machine learning, standardized values of the amplitudes at channels over the visual cortex and those of the mean opinion scores were selected for student and teacher datasets, respectively. A data resampling technique was also applied to the skewed datasets. The classification accuracy of this subject- and image-independent model was 0.73.

43.3014 **Feature interactions under high dynamic range (HDR) luminance visual recognition** Chou Hung[1], Andre Harrison[1], Anthony Walker[1,2], Min Wei[1,2], Barry Vaughan[1]; [1]Human Research and Engineering Directorate, US Army Research Laboratory, [2]DCS Corp

Visual search in the real world occurs under luminance contrast ratios up to 1,000,000:1, but models of search behavior are based on laboratory tests at ~100:1 contrast ratio. Recent reports of brightness perception have revealed non-linear effects of luminance normalization at contrast ratios over 1000:1 ('high dynamic range (HDR) luminance'), expanding the perceived shadings of gray at the mode of the luminance distribution (Allred et al 2012). We hypothesize that, because visual neurons encode both luminance/color and shape features, luminance and shape processing interact non-linearly during visual recognition under HDR luminance. We predict that target/distractor discriminability increases (camouflage is weaker) when both target and distractors are at modal luminance versus when both are antimodal. Here, we propose a framework to test this hypothesis and to model the underlying cognitive mechanisms. We are measuring EEG, eye tracking, and visual recognition behavior under rapid serial visual presentation (RSVP, 1-2 Hz). Stimuli consist of Gabors and grayscale-rendered objects presented on a 5 × 5 grid of luminance patches. Subjects indicate target detection (orientation or object category) via keypress. The primary independent variables are the HDR luminance distribution of the patches (whether the target and distractor patch luminance are at the mode or anti-mode of the distribution) and target/distractor similarity (Gabor orientation similarity or object feature similarity). Secondary independent variables include the eccentricity of the target and the eccentricity and temporal dynamics of the luminance patches. Dependent variables include behavioral response time and accuracy, stimulus and ocular-locked EEG amplitude, latency and frequency, and pupil size. The primary effect of interest is the dependence of these variables on the interaction of HDR luminance distribution and target/distractor similarity. We model the effect by varying the local adaptation levels within the visual field based on the distribution of background luminance vs target luminance at different eccentricities.

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SPATIAL VISION: MODELS

Monday, May 22, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

43.3015 **What internal noise source limits peripheral vision?** Denis Pelli[1,2](denis.pelli@nyu.edu), Hörmet Yiltiz[1]; [1]Psychology Dept., NYU, [2]Center for Neural Science, NYU

Pelli & Farell (1999) showed that visual sensitivity can be factored into efficiency and equivalent input noise Neq. Efficiency is only weakly dependent on size and nearly independent of eccentricity (Rosen & Pelli, submitted to JOV), so the strong dependence of visual sensitivity for simple targets on size and eccentricity is due to changes in the equivalent input noise. In the fovea, Pelli & Raghavan (Cosyne 2016) showed that the equivalent input noise is a sum of photon noise and a cortical noise. The photon noise Nphoton depends only on luminance, and is independent of letter size; the cortical noise is proportional to letter area A. Thus, Neq = Nphoton + aA, where a is a constant. We extended their measurements to the periphery, measuring threshold energy E for identification of a letter of size 0.5 to 16 deg at eccentricities 0 to 32 deg with and without a white noise background (RMS contrast 0.26). We estimated the equivalent input noise Neq = N E0/(E-E0), from the threshold energy E in noise, threshold energy E0 without noise, and noise power spectral density N. Supposing that the periphery is like the fovea, but scaled by the cortical magnification factor, we had expected to find that the cortical noise term, like cortical magnification, would depend on eccentricity. However, the data reveal a simpler result, and are well fit by Pelli & Raghavan's foveal equation with an additional term that is proportional to eccentricity , Neq = Nphoton + aA + b, where b is a constant. We tentatively attribute this new noise term to the density of retinal ganglion cell spikes, which is inversely proportional to eccentricity.

43.3016 **Predicting perceptual distortion sensitivity with gain control models of LGN** Alexander Berardino[1](agb313@nyu.edu), Valero Laparra[2], Johannes Ballé[1,3], Eero Simoncelli[1,3]; [1]Center for Neural Science and Courant Institute of Mathematical Sciences, New York University, [2]Universitat de Valencia, [3]Howard Hughes Medical Institute

We compare several functional models of LGN population response in terms of their ability to predict human judgments of visual distortion. The model-derived Fisher Information matrix provides a bound on discrimination thresholds for the visibility of arbitrary distortions. In particular, the largest and smallest eigenvectors of this matrix represent the model-predicted most- and least-noticeable distortions that can be added to a given image. We used a two-alternative forced-choice task to measure the ability of human observers to detect distortions corresponding to addition of multiples of these eigenvectors. Results are quantified using the difference, D, of the log amplitude thresholds for detection of the two eigen-distortions. Two randomly-chosen distortion vectors would yield approximately D = 0, and larger values of D indicate that model sensitivity is better aligned with that of human perception. We tested four nested models: a linear model, a luminance normalized model (LN), a contrast normalized model (CN), and a contrast normalized model with separate On and Off pathways (On-Off). Parameters of each model were set by fitting to the TID 2008 database of human perceptual judgments. We found that each successive level of normalization increased our measure of human sensitivity alignment, (D: Linear, 4.36; LN, 6.85; CN, 8.16; On-Off, 8.62), suggesting that hierarchical normalization, even at the early stages of the visual system, plays a significant role in human perceptual sensitivity to complex stimuli. On the other hand, our crossvalidated correlation with the database(Pearson R: Linear, .66; LN, .74; CN, .83; On-Off, .82), revealed that the On-Off model did not increase over the CN model. We conclude that our method, based on synthesis of model-optimized stimuli, exposes representational limitations and capabilities that cross-validation on curated datasets does not.

Acknowledgement: HHMI

43.3017 **Selectivity, hyper-selectivity and the tuning of V1 neurons** David Field[1](djf3@cornell.edu), Kedarnath Vilankar[1]; [1]Department of Psychology, Cornell University

We explore two forms of selectivity in sensory neurons. The first form is the traditional linear or 'basis selectivity' that is revealed by the classical receptive field. This receptive field traditionally describes the response of a neuron as a function of position. This receptive field will also typically represent the stimulus that optimally stimulates the neuron. The second type of selectivity we describe as "hyper-selectivity" and is either implicitly or explicitly a component of several models including sparse coding, gain control, some linear non-linear (LNL) models and deep-networks. Hyper-selectivity is unrelated to the stimulus that maximizes the response. Rather, it is the drop-off in response around that optimal stimulus that determines the hyper-selectivity. Models with hyper-selectivity allow what appear to be paradoxical results. For example, it is possible for a neuron to be very narrowly tuned (hyper-selective) to a broadband stimulus - or broadly tuned to a narrow-band stimulus (linear selectivity). We note that the Gabor-Heisenberg tradeoffs apply to selectivity with linear neurons. However, non-linear neurons that are hyper-selective can easily break this limitation, and we show this with both sparse coding and published data from V1 neurons. We also argue that results with over-complete sparse coding typically focus on the linear selectivity, but the hyper-selectivity changes in important and systematic ways as the network becomes more overcomplete. We show that the receptive fields of neurons, when measured with spots or gratings, will misestimate the optimal stimulus for the neuron. For four times overcomplete codes, we find that the estimates are in the range of 40 degrees. Finally, we argue that although gain control models, some linear non-linear models, and sparse coding have much in

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common, we believe that our approach to hyper-selectivity provides a deeper understanding of why these non-linearities are present in the early visual system.

Acknowledgement: Google Faculty Research Award

43.3018 **Lateral Context Effects on Contrast Pattern Detection and Discrimination** John Foley[1](foley@psych.ucsb.edu); [1]Department of Psychological and Brain Sciences, University of California, Santa Barbara

Several studies have shown that lateral patterns can affect contrast detection, discrimination, and perceived contrast. The presence of lateral patterns may increase or decrease thresholds and perceived contrast. Some of the results are inconsistent and there is no comprehensive model of these phenomena. Method: In five experiments two-alternative temporal forced choice was used to determine the detection and contrast discrimination thresholds of disk gratings and Gabor patterns in the presence of simultaneously presented context patterns, which were either lateral to or superimposed fully or partially over the target pattern. The context stimuli were disk gratings, concentric annular gratings or Gabor patterns. Spatial frequency was 4 c/d and duration was 100 msec. Thresholds were measured as a function of the type, position, size, and contrast of the context stimuli. Four to six observers performed each experiment. Results: The function relating the detection threshold to the contrast of the context pattern changes from dipper-shaped to monotonic increasing to dipper-shaped as the eccentricity of the context pattern increases. Gabor flankers have larger, but otherwise similar effects. When there is a pedestal, abutting annular gratings increase thresholds at low pedestal contrasts and decrease thresholds at high pedestal contrasts. When there is a gap, an annular grating decreases thresholds at both low and high pedestal contrasts. When mask gratings of different sizes are superimposed over the target, the threshold vs mask contrast function becomes steeper and then very shallow as the mask size increases beyond the target. Model: These diverse effects are described by an elaboration of a model of pattern context effects (Foley, 1994). The model estimates the excitatory and inhibitory effects of the context patterns. Lateral patterns increase excitation multiplicatively and increase inhibition additively. Both effects decrease with eccentricity. Excitation decreases more rapidly and then increases slightly, becoming more dominant at large eccentricities.

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43.3019 **Introducing a Time Efficient Model for Spatial Contrast Detection Based on Wavelet Transform, Suitable for Practical Applications** Hamed Hooshangnejad[1](h.hooshangnejad@gmail.com), Shahriar Gharibzadeh[2], Farzad Towhidkhah[3]; [1]Research Assistant, Department of Biomedical engineering, Amirkabir University of Technology, [2]Associate Professor, Department of Biomedical engineering, Amirkabir University, [3]Professor, Department of Biomedical engineering, Amirkabir University of Technology

Models of spatial contrast detection have a wide range of applications in vision science and machine vision, including display measurements, feature detection, letter identification, Standard Spatial Observer, and retina implants. This wide range of applications has always inspired vision scientists to develop more accurate models. In 2005, Watson and Ahumada introduced a computational model which was the most accurate model at its time. Their model could achieve the RMS error of 0.79 dB using Gabor Filter Banks. However, its execution time (20 seconds/43 stimuli of ModelFest Dataset) and computational load were so high that Watson and Ahumada proposed the omission of spatial frequency channels for reducing the model's required runtime for practical purposes. While this measure decreases runtime, it causes a significant increase in the RMS error. Further, the existence of frequency channels is mandatory for developing a more advanced and accurate model using Frequency Dependent Aperture Effect (FDAE). This need led us to develop a new model based on Wavelet Filter Banks that gives us the advantage of speed and capability to process each frequency channels' outputs. Using Wavelet Filter Banks and FDAE which were unprecedented on this dataset, we could achieve the as yet lowest RMS error as low as 0.68 and timing performance of 1 sec/43 stimuli. This model benefits from simplicity, efficiency and accuracy, which makes it suitable for cheaper, lighter and smaller hardware implementation; hence, it can be used in wide range of practical uses, such as online tests, real-time processes, an improved Standard Observer, and retina prostheses. Moreover, our model has also shown a better timing and error performance compared to one of the most recent models in this field, "Retina-V1". We also introduced a new formula for modeling contrast sensitivity function, with better timing performance and less error.

43.3020 **Building a better model of V1** Cheryl Olman[1](caolman@umn.edu), Adam Kohn[2], Thomas Naselaris[3], Jonathan Peirce[4], Odelia Schwartz[5]; [1]Department of Psychology, University of Minnesota, [2]Department of Neuroscience, Albert Einstein College of Medicine, [3]Department of Neurosciences, Medical University of South Carolina, [4]School of Psychology, Nottingham University, [5]Department of Computer Science, Miami University

Virtual V1sion is a collaborative coding and data sharing project intended to move our understanding of primary visual cortex (V1) forward faster and more efficiently. There are dozens, if not hundreds, of good examples of established and effective computational models that succeed in relating perception to presumed underlying neuronal responses or electrophysiology data to neuroimaging data. The best examples succeed in fitting behavioral, electrophysiological and neuroimaging data simultaneously. Virtual V1sion grows from the premise that these models should be accessible to all and built on a framework that allows ready comparison between models and between computational results and data from a range of modalities. On the one hand: V1 is the most studied region of the brain … why should we invest more effort in it? On the other hand: the fact that we know so much about V1 means it is possible to generate falsifiable hypotheses and collaborate on building a model that performs at a level that cannot be accomplished with data and computational expertise housed in a single laboratory. The successes we have had with Virtual V1sion so far center on population-level models using divisive normalization to simulate interactions within and between classical and extra-classical receptive fields. Success is defined along several dimensions: improved fits to data of multiple modalities; improved visualizations and simulations of population-level responses that help the experimenter design and interpret fMRI experiments; reduction of the total number of models considered, after demonstrating that different model elements are equivalent or redundant or not relevant. We are presenting those successes and soliciting contributions and critiques of the framework, so on-going design choices can maximize accessibility and utility for all.

43.3021 **A connectionist account of lateralized categorical and coordinate visual processing.** Vishaal Prasad[1](v2prasad@ucsd.edu), Ben Cipollini[1], Garrison Cottrell[1]; [1]Computer Science, University of California, San Diego

The two hemispheres of the brain exhibit lateralization in processing visual stimuli, such as faces, Navon stimuli, and frequency gratings. Our "differential encoding" computational model accounts for these differences via a hypothesized asymmetry in the length of long-range lateral connections in the visual cortex. Here we show this model also matches human data in categorical and coordinate processing, and provide data that break a long-standing assumption in the field. Coordinate discriminations involve absolute positional judgments; categorical discriminations involve relative positional judgments. Kosslyn (1987) hypothesized that, due to relatively better low frequency processing, coordinate discriminations are right hemisphere dominant, whereas, due to relatively better high frequency processing, categorical discriminations are left hemisphere dominant. Slotnick et al. (2001) posited that task difficulty explains the inconclusive data in intervening years. Our model replicated the human data's lateralization patterns on Slotnick's stimuli--including the blob dot coordinate case where Slotnick contradicted Kosslyn's hypothesis. They resolved this anomalous result by stratifying along difficulty. Our model similarly increases lateralization when resources are limited, thereby making the task more difficult; however, task stratification results do not align with Slotnick's results. The post-hoc nature of the paper's analysis and inconsistencies across its figures raise questions on whether difficulty stratification adequately explains the anomalous result. Frequency analysis of our model associates task-relevant content of the blob dot coordinate experiment with high frequencies, not low frequencies, similar to categorical experiments. This suggests that Kosslyn's original hypothesis made a faulty assumption: coordinate and categorical stimuli do not perfectly correlate with low and high frequency information. The differential encoding model matches human results with reference to a specific neural computation, anatomical source, and a specific neurodevelopmental mechanism. We hope these results will motivate the vision community to explore intra-cortical connectivity in visual processing and how lateralization can inform us about human visual processing.

43.3022 The Density Effect in Centroid Computation Jordan Rashid[1](jrashid@uci.edu), Charles Chubb[1]; [1]University of California, Irvine

Human vision is highly efficient in estimating the centroids of spatially scattered items. However, the computations underlying this remarkable skill remain poorly understood. A salient fact is that in estimating the centroids of dot-clouds, observers underweight densely packed dots relative to isolated dots (Mooreland & Boynton, 2016). A simple theory of this effect proposes that the centroid estimation process operates not directly on the input stimulus but rather on a version of the stimulus that has been preprocessed by (1) a low-pass filter followed by (2) a compressive nonlinearity. This model predicts that closely adjacent dots of opposite contrast polarity should exert very little weight in centroid estimates compared to dots of the same polarity. We tested this prediction in a centroid task using brief (150 ms) clouds that mixed 9 white and 9 black dots on a gray background. On each trial the observer strove to mouse-click the centroid of the stimulus cloud weighting all dots equally. Data were well described by a model that allowed the weight exerted on the subject's response by a given dot to depend on the peripherality of the dot in the stimulus cloud as well as on the density of same-polarity and opposite-polarity dots surrounding the dot. Density (orthogonalized relative to peripherality) exerted a large influence, modulating the weight exerted by stimulus dots on the order of ± 50% for most observers. Contrary to the predictions of the simple theory above, closely adjacent dots of opposite vs. the same polarity exerted equal influence on centroid estimates. A simple explanation of our results is that dot contrasts are rectified before the linear filter is applied. This could be accomplished as follows: (1) add together the responses of on-cells and off-cells, (2) low-pass filter the result, and (3) apply a compressive nonlinearity.

43.3023 Testing an Early Vision Model on Natural Image Stimuli Heiko Schütt[1,2,3](heiko.schuett@uni-tuebingen.de), Lars Rothkegel[2], Hans Trukenbrod[2], Ralf Engbert[2], Felix Wichmann[1,4,5]; [1]Neural Information Processing Group, University of Tübingen, Germany, [2]Experimental and Biological Psychology, University of Potsdam, Germany, [3]Graduate Training Centre of Neuroscience, University of Tübingen, Germany, [4]Bernstein Center for Computational Neuroscience, Tübingen, Germany, [5]Max Planck Institute for Intelligent Systems, Tübingen, Germany

Early visual processing has been studied extensively over the last decades. From these studies a relatively standard model emerged of the first steps in visual processing. However, most implementations of the standard model cannot take arbitrary images as input, but only the typical grating stimuli used in many of the early vision experiments. Previously we presented an image based early vision model implementing our knowledge about early visual processing including oriented spatial frequency channels, divisive normalization and optimal decoding (Schütt & Wichmann, VSS, 2016). The model explains the classical psychophysical data reasonably well, matching the performance of the non-image based models for contrast detection, contrast discrimination and oblique masking data. Here we report tests of our model using natural images, exploiting the benefits of image based models of visual processing. First, we assessed the performance of the model against human observer thresholds for detecting noise Gabors masked by patches of natural scenes (Alam et. al., JoV, 2014). Our model predicts the thresholds for this masking experiment well, although it slightly overestimates the sensitivity of observers. Second, we investigated the channel activities for natural scene patches fixated by observers in a free viewing eye movement experiment. Before normalization channel activities follow typically observed biases of natural scenes, including the decline in energy over spatial frequency and the stronger activity along the cardinal axes. After divisive inhibition, the distribution activity is no longer skewed towards low spatial frequencies, while the preference for cardinal axes is preserved. Finally, we observe that the channels are extremely sparsely activated: each natural image patch activates few channels and each channel is activated by few stimuli. Thus our model is able to generalize from simple grating stimuli to natural image stimuli, and it reproduces normative desiderata stemming from the efficient coding hypothesis and natural image statistics.

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43.3024 Submasking: A Key Factor in Human Pattern Vision Stephen Sebastian[1](sebastian@utexas.edu), Wilson Geisler[1]; [1]Center for Perceptual Systems, University of Texas at Austin

One of the most fundamental natural visual tasks is the detection of specific target objects in the environments that surround us. It has long been known that the properties of the background have strong effects on target detectability. The most well-known properties are the luminance, contrast, and similarity of the background to the target. In a previous study, we showed that these properties have highly lawful effects on detection in natural backgrounds, and that human detection performance is strongly linked to the statistics of natural scenes (Sebastian et al., under review). However, there is another important factor affecting detection in natural backgrounds that has received little or no attention in the masking literature, which has been largely concerned with detection in simple backgrounds. Namely, in natural backgrounds the properties of the background often vary under the target, and hence the target is not uniformly masked by the background (i.e., some regions of the target are masked/occluded more than others). We refer to this effect as submasking. To begin studying this factor we measured detection thresholds in simple independent-noise backgrounds where the luminance, contrast, or texture orientation varied under the target. In each case, the backgrounds were designed so that a classic matched template (MT) detector performed equally well whether or not the background varied under the target. This classic matched template detector is the optimal detector for backgrounds that do not vary under the target. However, for backgrounds that vary under the target, we show that the optimal detector weights each pixel location by its estimated reliability. We found that human performance tracks the performance of the reliability-weighted matched template (RWMT) detector. We demonstrate that humans make use of this same principle when detecting targets in natural backgrounds.

43.3025 Spatiotemporal maps of quantal noise, dark light and late neural noise limiting contrast sensitivity Daphne Silvestre[1](daphne.silvestre@inserm.fr), Angelo Arleo[1], Remy Allard[1]; [1]Sorbonne Universités, UPMC Univ Paris 06, INSERM, CNRS, Institut de la Vision, 17 rue Moreau, 75012 Paris, France.

As retinal illuminance increases, contrast sensitivity passes from a linear range (i.e., proportional to luminance) to a de Vries-Rose range (i.e., proportional to the square root of the background luminance) to a Weber range (i.e., independent of luminance). It is generally admitted that contrast sensitivity is limited by quantal noise (i.e., absorption probability) in the de Vries-Rose range, by spontaneous activity at the retina level (i.e., dark light) in the linear range and by neural noise occurring after contrast normalization in the Weber range. The target of the current study was to measure the spatiotemporal maps of these three internal noises in order to differentiate the spatiotemporal and luminance range of these three internal noise sources and better characterize the internal factors limiting contrast sensitivity. Contrast thresholds to flickering gratings were measured with and without external noise over a wide range of spatiotemporal frequencies and retinal illuminance. For each spatiotemporal frequency, contrast thresholds as a function of retinal illuminance enabled us to estimate the levels of the three internal noises (quantal, dark light and late neural), which were then used to build the three corresponding spatiotemporal maps. These maps led us to elaborate a model characterizing the factors limiting contrast sensitivity as a function of spatial and temporal frequencies.

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43.3026 Towards matching peripheral appearance for arbitrary natural images using deep features Thomas Wallis[1,2,8](thomas.wallis@uni-tuebingen.de), Christina Funke[1,2,8], Alexander Ecker[1,2,3], Leon Gatys[1,2], Felix Wichmann[4,2,5], Matthias Bethge[1,2,6,7]; [1]Werner Reichardt Centre for Integrative Neuroscience, Eberhard Karls Universität Tübingen, [2]Bernstein Centre for Computational Neuroscience, [3]Department of Neuroscience, Baylor College of Medicine, [4]Neural Information Processing Group, Faculty of Science, Eberhard Karls Universität Tübingen, [5]Empirical Inference Department, Max Planck Institute for Intelligent Systems, Tübingen, [6]Institute for Theoretical Physics, Eberhard Karls Universität Tübingen, [7]Max Planck Institute for Biological Cybernetics, Tübingen, [8]Equal first authorship

Due to the structure of the primate visual system, large distortions of the input can go unnoticed in the periphery, and objects can be harder to identify. What encoding underlies these effects? Similarly to Freeman & Simoncelli (Nature Neuroscience, 2011), we developed a model that uses summary statistics averaged over spatial regions that increases with retinal eccentricity (assuming central fixation on an image). We also designed the averaging areas such that changing their scaling progressively discards more information from the original image (i.e. a coarser model produces greater distortions to original image structure than a model with higher resolution). Different from Freeman and Simoncelli, we use the features of a deep neural network trained on object recognition (the VGG-19; Simonyan & Zisserman, ICLR 2015), which is state-of-the art in parametric texture synthesis. We tested whether human observers can discriminate model-generated images from their original source images. Three images subtending 25 deg, two of which were physically identical, were presented for 200 ms each in a three-alternative temporal oddity paradigm. We find a model that, for most original images we tested, produces synthesised images that cannot be told apart from the originals despite producing significant distortions of image structure. However, some images were readily discriminable. Therefore, the model has successfully encoded necessary but not sufficient information to capture appearance in human scene perception. We explore what image features are correlated with discriminability on the image (which images are harder than others?) and pixel (where in an image is the hardest location?) level. While our model does not produce "metamers", it does capture many features important for the appearance of arbitrary natural images in the periphery.

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43.3027 **The Structure of Visual Space** Michael Herzog[1](michael.herzog@epfl.ch), Aline Cretenoud[1], Gregory Francis[2], Lukasz Grzeczkowski[1,3]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, [2]Purdue University, West Lafayette, IN, USA, [3]Ludwig-Maximillian University of Munich, Germany

In cognition and everyday life, common factors are frequently encountered. For example, grades in physics correlate well with grades in mathematics. What about vision? We will first show that performance levels in 19 versions of the Ebbinghaus illusion correlated very strongly. For example, observers adjusted the centre disk in the classic Ebbinghaus illusion or a centre square surrounded by other squares. Performance strongly correlated for this and all other versions, including static and dynamic ones (n=87). Hence, there is a factor for the Ebbinghaus illusion. Next, we correlated the illusion susceptibility for the classic Ponzo and Müller-Lyer illusions (line drawings) and corresponding real world versions (pictures). In 86 new observers, we found almost no significant correlations. In the third experiment with 113 new observers, we tested six classic illusions, including the Ebbinghaus, the Müller-Lyer and the Ponzo illusion, and found, again, mainly Null results, except for a moderate link between the Ebbinghaus and Ponzo illusion. Hence, there seems to be no general factor for illusion strength, but sporadic associations. In the fourth experiment with 15 new observers, we tested seven similar illusions and four personality traits, including cognitive disorganization and mental imagery. Again, illusions were only weakly correlated but we found a significant and reliable association between the Ponzo illusion and both cognitive disorganization and mental imagery. We found similar results with other visual paradigms than illusions. We propose that the visual space comprises extremely small factors (Ebbinghaus factor), which may be linked to other visual factors- in a way we are far from understanding at the moment. To understand the mechanisms common to vision, we need to use batteries of tests and publish Null results, things that are not very common in our field.

Acknowledgement: Learning from Delayed and Sparse Feedback" (Project Number: CRSII2_147636) of the Swiss National Science Foundation (SNFS)

43.3028 **Identifying, avoiding and dealing with convergence failures in maximum-likelihood estimation of the psychometric function.** Nicolaas Prins[1](nprins@olemiss.edu); [1]Department of Psychology, College of Liberal Arts, University of Mississippi

Maximum-likelihood estimation of the parameters of a psychometric function typically occurs through an iterative search for the maximum value in the likelihood function defined across the parameter space. This procedure is subject to failure. First, iterative search procedures may find a local, not global, maximum in the likelihood function. This issue can be adequately avoided by performing a brute-force search through a sufficiently fine-grained grid across parameter space and using the highest likelihood in the grid as a seed for a subsequent iterative search procedure. However, the procedure also fails when the likelihood function does not contain a maximum. This is the case when either a step function or a constant function is associated with a higher likelihood than the model function can attain with finite parameter values. In such cases iterative search procedures may erroneously report having successfully converged on a maximum in the likelihood function. The parameter estimates that result from such false convergences are largely arbitrary. As such, the estimates of parameters, their standard errors and confidence intervals, whose derivation included such false convergences will be systematically inaccurate. Here I describe a method by which false convergences can be reliably detected. Using simulations, I systematically investigate how stimulus placement, number of trials, parameters estimated, and task (2AFC, 4AFC, etc) affect the probability that the likelihood function will not contain a maximum at finite parameter values. Importantly, simulations indicate that as long as a real maximum exists in the likelihood functions of both the data as well as bootstrap simulations, standard errors derived by a standard bootstrap procedure are essentially unbiased. This result holds across a wide variety of stimulus placement strategies, including adaptive placement strategies, pattern of free parameters, and tasks.

Spatial Vision: Neural mechanisms

Monday, May 22, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

43.3029 **Stability of Repeated Measures of Contrast Sensitivity Across Spatial Frequency** Russell Adams[1,2](michelem@mun.ca), Michele Mercer[1]; [1]Department of Psychology, Faculty of Science, Memorial University, St Johns, NL Canada, [2]Discipline of Pediatrics, Faculty of Medicine, Memorial University, St Johns, NL Canada

Purpose: It is now well accepted that contrast sensitivity (CS) is the most comprehensive single measure of human spatial vision and an emerging clinical tool, especially for assessing patients undergoing refractive surgery and those with retinal and neuro-ophthalmic pathology. Despite its scientific and clinical merits, there are few data on the metrics of CS measurement, perhaps most critically, the stability of assessment across time. Here we provide these results for two of the most predominant sine wave based tests of spatial CS. Methods: Using a standard staircase procedure, right eyes from 15 healthy emmetropic adults (18- 53 yr.) were tested 5-10 times repeatedly (M = 2.4 days between tests) with both the FACT (Vistech) and Vector Vision tests under standard photopic conditions. Contrast thresholds at each spatial frequency (1.5 to 18 c/deg) were obtained, with both test and SF order counterbalanced across trials. Given the repeated tests, participants were not given feedback at any point during the procedure. Results: Performance across tests was very consistent for both tests, especially at mid spatial frequencies. On average, adults differed by 0.30, 0.13, 0.15, 0.22 and 0 .29 CS octaves (an octave is a halving or doubling of CS) at 1.5, 3.0, 6.0, 12.0 and 18.0 cy/deg, respectively. ANOVA and post hoc analyses revealed that there were differences between spatial frequency ($p < 0.01$), with relatively greatest stability at 3.0 and 6.0 cy/deg. Conclusions: At least among those with normal vision, multiple measurements of contrast sensitivity yield highly consistent and stable estimates of spatial vision. In addition to the implications for measurements of contrast sensitivity in lab settings, this result is of critical importance for clinicians as it implies that patient changes in CS during the course of assessment and treatment likely reflects true degradations or improvements in the underlying optical and neural substrate.

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43.3030 Cortical Correlates of Aberrant Vernier Acuity in Albinism

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Introduction: Albinism is a family of genetic diseases that cause aberrations in melanin synthesis which in turn cause aberrations in retinal development, cone density, retinocortical connectivity, and vernier acuity (VA). In healthy individuals, VA is believed to be limited by neural sampling in V1 (primary visual cortex)1. So, we asked if albinism-related deficits in VA might similarly reflect aberrations in retinocortical mapping. Methods: VA and fMRI data were obtained from 4 albinism patients (1M,3F,ages 18-31) and 4 control subjects (3M,1F,ages 20-41). VA thresholds (minimum angle of resolution, MAR) along the horizontal meridian of the left visual field were measured at 10-11 loci ranging from 0-20 degrees eccentricity using a three-dot vertical vernier stimulus. Cortical magnification (CM) was measured at 1.875x1.875x2.5 mm resolution over the same visual field range using fMRI mapping with checkered rings/wedges and a General Electric 3 Tesla MRI scanner2. Results: Overall, albinism patients had higher VA thresholds (mean foveal MAR ± SD: 5.990 ± 7.188 arcmin) than controls (0.498 ± 0.127 arcmin). MAR for controls was a power function of cortical magnification (MAR=11.15 x CM-1.192). This was also true for albinism patients, but with much more quantitative variation ranging from virtually normal (MAR = 7.68 x CM-1.373) to grossly aberrant (MAR = 107.3 x CM-1.106). Surprisingly, the two albinism patients with the most disparate VA vs CM functions had nearly identical foveal peak cone densities (46,019 vs 50,402 cones/mm2). Conclusions: Although VA varies widely across patients with albinism; it retains the quantitative relationship (power function) with CM observed in controls, albeit with wide quantitative variation. This latter variation, at least in some cases, is poorly correlated with cone densities thus emphasizing the importance of post-receptoral factors as determinants of overall visual function in albinism. 1. Duncan PMID: 12765616 2. DeYoe ISBN 978-1-4419-0345-7

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43.3031 Individual differences in contrast sensitivity functions with and without adaptive optics: direct estimates of optical and neural processes in young and elderly adults using factor analysis

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Elliott et al. (2009) measured contrast sensitivity functions (CSFs) in young and elderly adults, using both normal viewing and closed-loop adaptive optics (AO) to correct high-order aberrations. To better characterize optical and neural processes, we reanalyzed these data using factor analytic techniques developed to estimate the number and tuning of spatial mechanisms (Peterzell, 1991; 2016). Log CSFs for 16 individuals, spanning two age groups (18-29, and 76-82 years), were measured using 2AFC for six horizontal, monocular sinewave gratings between spatial frequencies of 0.55 and 18 cpd . An oblique solution (direct oblimin) revealed three factors. The first loaded onto all AO data at and above 1.25 cpd, and also onto 1.25 cpd in the non-AO condition. This high frequency factor represents variability in neural or retinal contrast sensitivity consistent with parvocellular processing. The second factor loaded onto low frequencies (0.55 to 2.25 cpd, for both AO and normal viewing). It represents neural contrast sensitivity below 2.25 cpd, but also accounted for uncorrected contrast sensitivity at low frequencies (i.e., optical aberrations did not influence sensitivity at low frequencies). This is consistent with magnocellular processing. The third factor loaded onto 4.5 cpd and higher, but only for the normal, non-AO condition. This factor clearly represents optical quality as it was eliminated under AO correction. In sum, two neural factors were revealed when the optical factor was removed, either due to the specific frequency being tested (e.g., low frequencies are nearly un-affected by optical factors) or due to AO correction, and one optical factor was revealed at high frequencies with no AO correction. However even with optical aberrations removed temporarily, individual differences in the neural factors correlated with individual differences in uncorrected optics. Older individuals tended to have a poorer optical quality, but also showed less contrast sensitivity in both neural factors.

43.3032 Heritability of visual perception and cortical architecture

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Individual observers show reliable biases in perception across the visual field, which are stable across time (Afraz et al., 2010). Furthermore, biases for perceiving stimulus size correlate with individual spatial tuning properties in V1 (Moutsiana et al., 2016). Previous studies have shown that brain volume, cortical thickness, and surface area of the brain are highly heritable (e.g. Baaré et al., 2001). Here we explore the heritability of perceptual heterogeneity and functional cortical architecture in early visual cortex using behavioral and functional magnetic resonance imaging (fMRI) measures in a classical twin design. In particular, we compare correlations of size perception biases, higher-order ambiguous perception biases (Rubin's vase; Rubin, 1915), and population receptive field (pRF) parameters between monozygotic and dizygotic twins. Behavioral results showed a significantly greater between-subject correlation of size perception biases for monozygotic than dizygotic twins. However, there was no evidence of a heritable component for the distribution of size biases across the visual field. There was no compelling evidence for heritability effects in higher-order biases for perceptually ambiguous stimuli. Our fMRI results found no evidence for higher correlations between monozygotic compared to dizygotic twin pairs with regard to pRF sizes or cortical magnification factor. However, we do see evidence for higher correlations between monozygotic than dizygotic twin pairs for the surface area of early visual cortex regions, even after normalising to total surface area. These findings suggest that there may be some genetic component in size perception, but perceptual heterogeneity across the visual field for size perception is not strongly heritable. We find no clear evidence of a genetic component for high-level perceptual biases or fine-grained measures of functional architecture in early visual cortex.

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43.3033 The effects of visual surround on multifocal visual evoked potentials

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When studying the effects of surround on visual evoked potentials (VEPs), it is important to design experiments that separate responses to the stimulus and surround. Multifocal paradigms allow for fully de-correlated stimulation of different regions of visual space, and previous studies of mfVEPs have shown that components the K2.1 and K2.2 kernels appear to be of magnocellular and parvocellular origins respectively. Hence we propose that the technique could be used to investigate the effects of visual surround, and furthermore could allow for neurophysiological dissection of surround effects. Here we report the results from experiments on the effects of red vs. green surround ($N = 15$) and parallel vs. orthogonal surround ($N = 9$) on mfVEPs. In both experiments, the first order evoked responses were unaffected by the surround. For the coloured surround experiment, we observed a significant reduction in the N100-P150 amplitude of the K2.2 response for red cf. green surround ($F(1,14) = 10.75$, $p = .005$, partial $\eta^2 = .43$). This finding suggests that red surrounds may increase the efficiency parvocellular responses. For the orientation experiment, we observed a significant reduction in the N60-P100 K2.1 amplitude with parallel surround at low spatial frequency ($t(8) = 2.52$, $p = .04$) but not at high spatial frequency ($t(8) = .014$, $p = .99$). This finding is consistent with evidence that orientation selective suppression is a predominantly magnocellular phenomenon. Together, these results indicate that mfVEP is a useful technique for investigating the effects of surround on visual processing.

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43.3034 Phase analysis of SSVEP reveals that masking delays neural response in human cortex

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Although the amplitudes of steady-state visual evoked potentials (SSVEP) are frequently used to quantify neural responses, past work has often neglected their phases. However, neural latencies generally decrease as response amplitudes increase (e.g. Albrecht, 1995), suggesting that SSVEP phases could contain valuable information. We measured SSVEP amplitudes and phases in response to gratings that varied in contrast, both when presented alone and when presented superimposed on a second, constant-contrast "masking" grating. We recorded SSVEP signals from 4 electrodes placed over the occipital lobe while participants (n=8) viewed 1.5 sec stimulus presentations. A vertical grating phase-reversed at 15 Hz and varied between 3.125-25% contrast in logarithmic steps. In the no-mask condition, the vertical grating was presented alone, while in the masked condition, it was superimposed on a horizontal grating that had a fixed 25% contrast and phase-reversed at 6 Hz. The average 15 Hz SSVEP amplitude in the no-mask condition increased with contrast for the lowest contrast levels, but remained flat at high contrast levels. The phase of the 15 Hz response, however, advanced monotonically with increasing contrast ($p < 0.01$), indicating a steady decrease in neural latency. In the masked condition, increasing contrast elicited monotonic increases in the 15 Hz SSVEP amplitude, as well as monotonic advances in phase (both $p < 0.01$). Comparing masked and no-mask conditions showed that adding the second grating both reduced the amplitudes of the 15 Hz response at low contrasts ($p < 0.01$) and delayed their phases (both $p < 0.01$). These results are consistent with the masker weakening and slowing neural response. SSVEP phases, at least in the no-mask condition, appeared more sensitive to changes in effective stimulus strength than SSVEP amplitude. This sensitivity should allow future analyses to test specific models of the neural computations underlying visual masking.

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43.3035 Divisive normalization versus inhibition during visual motion integration in humans Michael-Paul Schallmo[1](schallmo@uw.edu), Anastasia Flevaris[1], Alex Kale[1], Rachel Millin[1], Raphael Bernier[2], Scott Murray[1]; [1]Psychology, University of Washington, [2]Psychiatry, University of Washington

The amount of time required to discriminate the direction of motion of a stimulus depends on its size and contrast in apparently complex ways. For example, at high contrast, large gratings require more time than those that are smaller. This effect is referred to as spatial suppression, as it is believed that large gratings stimulate suppressive receptive field surrounds, thereby reducing neural responses to stimuli within the receptive field centers. While the neural processes underlying this behavior are not fully known, recent evidence suggests a significant role for neurons in area MT. It is also not clear what role inhibition may play in this perceptual suppression effect. We show how a computational model that includes divisive normalization provides a unifying explanation for this perceptual behavior. Further, responses in human MT complex (hMT+) measured with fMRI reflected key predictions of the model, suggesting that divisive normalization performed in this region underlies visual motion integration in humans. Next, we examined the role of inhibition during spatial suppression using two different methodological approaches. First, we quantified the concentration of GABA in a region of lateral occipital cortex including hMT+ using MR spectroscopy. We found that higher GABA concentrations in this hMT+ region were associated with reduced motion duration thresholds overall, but not with stronger spatial suppression. Second, the effect of GABA was potentiated pharmaceutically via oral administration of lorazepam, a benzodiazepine which acts as a positive allosteric modulator of the GABAA receptor. Contrary to our spectroscopy findings, motion duration thresholds were modestly increased by lorazepam in a manner that was accounted for by the normalization model. Our results point to a critical role for divisive normalization in mediating spatial suppression, as well as a complex role for GABA in determining neural responsiveness, but not in directly scaling the strength of spatial suppression.

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43.3036 Spatially selective responses to both modal and amodal completion stimuli in human visual cortex D. Samuel Schwarzkopf[1,2](s.schwarzkopf@ucl.ac.uk), Benjamin de Haas[1,2]; [1]Experimental Psychology, University College London, UK, [2]Institute of Cognitive Neuroscience, University College London, UK

Parsing a visual scene requires the differentiation of foreground and background figures, which may be distinguished by luminance contrast edges. However, when two objects are colored identically, their contours can be inferred. Early visual cortex responds to illusory contours (modal completion) where abutting lines or collinear edges imply the presence of an occluding surface. Further, it has been shown that early visual cortex signals also encode occluded objects behind a surface (amodal completion; Ban et al., 2013). Here we used functional magnetic resonance imaging (fMRI) and population receptive field (pRF) analysis in normal healthy volunteers (n=7) to map the visual cortex with bar stimuli that traverse the visual field. Stimuli were either defined by modal or amodal completion or comprised a subtle luminance contrast. Meanwhile, participants performed an orthogonal detection task at fixation. All three conditions produced reliable retinotopic signals within V1-V3. Compared to a separate pRF mapping experiment using conventional stimuli, signal strength was considerably weaker and pRF size larger for all conditions. Importantly, we found no significant differences in activation or pRF size between the three experimental conditions. Our findings suggest the possibility that despite the orthogonal fixation task these conditions merely measured the topographic signature of spatial attention to the bar stimulus rather than any specific activation related to illusory contours or occlusion. This points towards a need for careful experimental design in future studies that seek to infer specific stimulus processing from retinotopic signals.

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43.3037 Differential orientation tuning of near and far surround suppression in human V1 Kiley Seymour[1,2,3], Susan Wardle[1,2]; [1]Department of Cognitive Science, Macquarie University, Sydney, Australia , [2]ARC Centre of Excellence in Cognition and its Disorders, Macquarie University, Sydney, Australia , [3]School of Psychology, UNSW Australia, Sydney, Australia

Responses to stimuli placed within a neuron's receptive field are modulated by stimuli in surrounding regions. Contextual modulation of neural responses in primary visual cortex (V1) is orientation-tuned. Human fMRI experiments show greater suppression of the BOLD response to a target stimulus when the target and surrounding stimuli are the same orientation, and weakest suppression when the target and surrounding stimuli are orthogonal. Monkey physiology and human psychophysics suggest that two distinct mechanisms underlie orientation-specific contextual suppression in V1. The first inhibits sensory responses from a short range and is strongly tuned for orientation (geniculo-cortical and horizontal V1 connections). The second involves long-range inhibition that is less orientation-tuned (feedback from extrastriate cortex). Here we aimed to examine the orientation-tuning of these two mechanisms in human V1 with fMRI by manipulating the spatial extent of the surround to selectively probe either short or long-range mechanisms. We measured fMRI BOLD responses to a target grating annulus (1.5-3.5 deg eccentricity) in the presence of six different surround stimuli in ten naive observers. Surrounds were either oriented parallel or orthogonal to the target grating and were one of three sizes (Full: 3.5-9.5 deg eccentricity, Near: 3.5-6 deg eccentricity, Far: 6-9.5 deg eccentricity). Observers completed an orientation-matching task at central fixation. For the full surround, we replicated the finding of greater suppression of the BOLD response to the target for parallel surrounds compared to orthogonal surrounds. Similar orientation tuning of contextual suppression was observed for the near surround. However, for the far surround there was no difference in suppression of the BOLD response for orthogonal versus parallel gratings, suggesting far surround suppression is un-tuned for orientation. Our findings from human V1 are consistent with the spatial extent of orientation tuning of surround suppression observed in macaque primary visual cortex and human psychophysics.

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43.3038 Prevalence of gain control effects in macaque visual cortex Christopher Shooner[1](shooner@nyu.edu), Luke Hallum[1], Jenna Kelly[1], J. Movshon[1], Michael Hawken[1]; [1]Center for Neural Science, New York University

Visual neurons adjust their responsivity based on the total contrast energy of a stimulus. Or do they? Following classic studies of the cat visual system, it has often been assumed that contrast normalization is a ubiquitous property of neurons in primary visual cortex (V1). The prevalence of this phenomenon in the primate brain, however, has not been confirmed experimentally; this test is of particular interest given the important differences in subcortical gain control between the species. We used a simple masking experiment to characterize how cortical responsivity changes with stimulus energy. We measured the responses of 150 V1 neurons in 4 opiate-anesthetized macaque monkeys to sinusoidal gratings with optimized spatiotemporal parameters and varying contrast. We obtained contrast-response curves in the presence and absence of a superimposed, orthogonal, masking grating of 50% contrast, and compared contrast gain between masked and unmasked conditions. The effect of the mask varied widely across the population, ranging from 100% gain reduction to slight gain enhancement. This pattern differs markedly from an idealized model of contrast normalization, in which cortical gain is reduced consistently in proportion to increased contrast. Additionally, we found a relationship between masking strength and spatial receptive field properties: cells showing less gain reduction tended to have smaller receptive fields and to prefer higher spatial frequencies, suggesting they may receive significant input from the parvocellular LGN. The parvocellular pathway, unique to primates, relays a linear representation of stimulus contrast which is not subject to the gain-control mechanisms shaping magnocellular responses. Our findings suggest that this veridical contrast signal is preserved in V1, alongside more conventional gain-controlled signals.

43.3039 Impact of foveal bias on estimates of population recpetive fields

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To date, the large majority of studies employing the population receptive field mapping (pRF) technique have employed a 2-D Gaussian model, whereby the pRF of a given voxel is predicted by a circlular aperture of center (x, y) and size (sigma). Although there is some evidence to suggest that the accumulation of receptive fields in a given V1 voxel roughly approximates a Gaussian, there is also reason to think there might be systematic deviations from this assumption, particularly in higher-order visual areas or close to the vertical and horizontal meridian. For example, receptive field mapping in monkey inferotemporal cortex (IT) reveals a foveal bias with the receptive fields of most neurons overlapping the foveal region. Combined with biases for the contralateral upper and lower visual fields within a given area, we tested the prediction that the most efficient way for a population of RFs to completely cover either a quadrant or hemifield and still overlap the fovea individually is for them to take an ellipitical shape with the primary axis orientated towards fovea. Here we analyze pRF mapping data in human participants with both the 2-D Gaussian and elliptical pRF implementations developed in AFNI. Our results reveal a significant correlation between eccentricity and aspect ratio within all identified retinotopic maps (V1-V4, V3A, V3B, LO1, LO2 & V7/IPS0). Further, for areas containing largely quadrant representations of the visual field (e.g. V2, V3), the average pRF shows a systematic orientation toward the fovea. Such foveally biased and elliptical pRFs suggest the possibility of greater transfer of information between fovea and an eccentric position than between two isoeccentric positions in different quadrants of the visual fieldz (e.g. V2d and V2v). The widespread assumption of circular pRFs may obscure observations of systematic pRF biases throughout visual cortex.

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OBJECT RECOGNITION: MODELS

Monday, May 22, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

43.3040 Three-dimensional objects are preferentially categorized using their medial axes

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Much work has stressed the importance of shape for object categorization (Wagemens et al., 2008), yet it is unclear what properties of shape allow for successful categorization. Here we tested whether the medial axis (MA), a summary representation of object shape, supports object categorization. There were two goals: first, to create a stimulus set of 3D objects with which to investigate MA processing, and second, to test whether adults preferentially categorize objects using the MA. One hundred and fifty objects were created such that some objects were identical in MA but differed in surface form (SF) and others were identical in SF but differed in MA (Figure 1). Using a forced-choice discrimination task (N = 83), we identified 20 objects whose MA and SF were matched for discriminability. Then, using a match-to-sample task (N = 25), we examined categorization on this novel stimulus set. On each trial, participants were shown a sample object and two choice objects, judging which of the two choice objects was most similar to the sample. Choice objects could match the sample in terms of MA, SF, or both. Critically, some trials consisted of a conflict between MA and SF, forcing participants to choose either the MA or SF for categorization. In the absence of conflict, participants successfully matched objects using both MA and SF information ($ps < 0.001$, $ds > 2.95$). In the conflict condition, participants preferentially chose the object that matched the sample in MA ($p = 0.003$, $d = 0.66$). These findings suggest that despite sensitivity to SF, 3D objects are categorized using the MA. This work lends support to the hypothesis that the MA is central to both shape perception (e.g., Firestone & Scholl, 2014) and object categorization.

43.3041 Interaction with physical objects to learn visual representations

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Recent advances in deep neural networks (DNN) have helped decode the nature of neural representations in the human visual cortex [1]. DNNs learn visual representations via a supervisory signal that optimizes an object category prediction cost function [2]. It is not clear however, if the brain explicitly uses such a supervisory signal. Other supervisory signals exist that results from sensory experience in the external world, for example grasping objects. The internal representations of DNNs trained on object grasping cost functions also generalize to ImageNet classification task [3]. In our study, we ask the question if visual representations learnt for object grasping correlate to neural responses in the visual cortex. We acquired BOLD fMRI data from 20 subjects who watched a 11 minute natural movie. We train two deep neural networks, one on object grasping and the other object prediction cost function. Using representation dissimilarity analysis (RDM), we compare RDMs of the learnt neural networks to the RDM to different brain ROIs such as V123, V4, LO and PHC for the movie stimuli. While DNNs trained for object recognition indeed correlates to the brain ROIs, we observe that the DNN trained for grasping objects also significantly correlate to the different visual areas. We further compare the internal representations of both these neural networks. Overall our results suggest that, visual representations can be learnt from real world physical interactions. [1]. Güçlü, U., & van Gerven, M. A. (2015). Deep neural networks reveal a gradient in the complexity of neural representations across the ventral stream. The Journal of Neuroscience. [2]. Krizhevsky, A., Sutskever, I., & Hinton, G. E. (2012). Imagenet classification with deep convolutional neural networks. In Advances in neural information processing systems. [3]. Pinto, L., & Gupta, A. (2015). Supersizing self-supervision: Learning to grasp from 50k tries and 700 robot hours.

43.3042 Towards a quantitative model of feeling beauty

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Philosophers claim that beauty is a kind of pleasure. We empirically investigate the perceptual processes underlying beauty experiences. In our experiments, participants continuously rate their pleasure while experiencing various stimuli (seeing images of various kinds, touching an unseen teddy bear, eating candy) and for another 60 s after. And, at the end of each trial, they rate their overall feeling of beauty on a four-point scale. We collected data under six conditions (presentation durations of 1 to 30 s, with or without adding a cognitive task). Here, we present a parsimonious mathematical account for the entire data set (680 trials). Continuous pleasure ratings are well summarized by a one-free-parameter model: Pleasure quickly approaches a steady-state level rsteady during stimulus exposure (exponential time constant of 2 s). After stimulus offset, it slowly decays (100 s time constant). Stimulus kind and condition affect only the amplitude rsteady, with no effect on the model dynamics. The effects of stimulus and condition are separable. Each condition (duration or added

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task) attenuates mean pleasure of all stimuli by the same gain factor. The proposed model is parsimonious and predicts the distribution of rsteady (r=0.57). Thirteen free parameters — one strength per stimulus, one gain per condition, and a pleasure variance — explain the data of all 32 trial types tested (nearly all combinations of 6 stimuli x 6 conditions). Across stimuli and conditions, means of pleasure and beauty are directly proportional. Adding just two parameters — a proportionality constant between pleasure and beauty and a beauty variance — extends the model to also account for the beauty ratings with excellent fidelity, r=0.90. In conclusion, our model fits demonstrate that the subjective experience of beauty can be modelled quantitatively. Our model makes several testable hypotheses, e.g., that each experimental condition equally attenuates the pleasure and beauty of all stimuli.

43.3043 Noise masking and crowding reveal two very different kinds of spatial integration.

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Recognition of a simple target, e.g. a letter, can be prevented by adding visual noise or nearby clutter. Both effects involve integration of visual information over space. The literature says that crowding integrates "features," and noise-masking integrates contrast energy. Here we compare the spatial extent of the two kinds of integration. For crowding, this spatial extent is called the "crowding distance" (or "critical spacing") and is well-known. For noise masking, we made new measurements. We added white noise (independent pixels) with a Gaussian spatial envelope centered on the letter target. This is like critical-band masking, but varying the extent ("band") in space. Suppose a detector that integrates over a fixed area. Its threshold would increase with noise radius until the radius goes beyond the fixed area. Indeed, that is what we found for letters varying in size from 0.5 to 16 deg, at eccentricities of 0 to 32 deg. We expected this noise-integration radius to match the crowding distance, but they are very different. The crowding distance is one third of the eccentricity, independent of letter size. The noise-integration radius is roughly the letter radius (half the size), independent of eccentricity. For a small letter at large eccentricity, the noise-integration radius is less than 1/10 the crowding distance. For a large letter at small eccentricity, the noise-integration radius is more than than 100 times the crowding distance. This reveals two fundamentally different kinds of spatial integration.

43.3044 Modeling the shape selectivity of single neurons of a macaque body patch

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We modelled the shape selectivity of single neurons of the midSTS body patch of macaques (Popivanov et al., J. Neurosci., 2014). We employed "adaptive stimulus sampling" (Brincat and Connor, Nat. Neurosci., 2004), producing shapes that were adapted on-line to the response of each single neuron during the recordings. This procedure resulted in a large number of shapes, eliciting a wide range of responses for each neuron. We fit quantitative models of shape selectivity to the responses of each neuron separately (n = 77). We employed cross-validation fitting procedures and the model's performance was evaluated with data that were independent from the training data. By ascending order of performance (median explained explainable variance), we fit 1) Curvature and Angular Position tuning models, adapted from Brincat and Connor (2004), in which the model neuron summates the output of a few subunits, each tuned for a combination of curvature, orientation and position (x-y coordinates) of contour elements, 2) Pixel gray level models that consist of a linear combination of pixel gray levels, 3) HMAX models, which are an implementation of the shallow convolutional network HMAX by Mutch and Lowe (2006) and 4) deep Convolutional Neural Network models (CNNs), specifically Alexnet and VGG19. The deeper pooling and convolutional layers (before the fully connected layers) of the CNNs performed best , resulting in a median explained explainable variance of the responses of up to 77%. These successful models consisted of a linear weighting (estimated by PLS regression) of the units of a single deep layer. Furthermore, the performance of the deeper layer CNN model neurons generalized to reduced stimuli of image parts and were largely invariant to scale, as real midSTS neurons. These data show that deep learning networks are unprecedented successful models of the shape selectivity of single neurons of the macaque midSTS body patch.

43.3045 Comparing response properties of V1 neurons to those of units in the early layers of a convolutional neural net

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Deep convolutional neural networks (CNNs) trained for object recognition contain units in their later layers that reflect an encoding somewhat similar to that in cortical areas V4 and IT. If it is also true that the earlier stages in these CNNs reflect response properties commonly observed in V1, then CNNs could offer a compelling image-computable model for understanding computations in the ventral stream. To test this, we measured the responses of the CNN known as AlexNet (Krizhevskyet al., 2012) to sinusoidal grating stimuli like those used extensively to characterize V1. We evaluated tuning for orientation, spatial frequency (SF), color, F1/F0 ratio and cross-orientation suppression. In a complementary approach, we directly analyzed the weights (rather than responses) of AlexNet for these properties. We found that the early layers contain an even coverage of orientation and SF, with bandwidths similar to those in V1, and with the second layer containing only complex cells. The 1st layer primarily consists of a group of luminance filters and a smaller group of chromatic filters, with the former tending to prefer higher spatial frequencies. Consistent with cross-orientation suppression, the 2nd layer weights have a sinusoidal relationship with the preferred orientation of their 1st layer inputs. We also tested an untrained network, and found that nearly all of these V1-like properties were absent. We conclude that a CNN can approximate several V1 response properties, and that optimizing for object recognition is sufficient to achieve these properties. Our results support the use of CNNs as a tool to understand how sophisticated cortical representations, for which we do not yet have good biologically plausible image-computable models, may arise from early cortical representations, for which a richer set of models already exists.

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43.3046 Evaluating the robustness of object recognition to visual noise in humans and convolutional neural networks

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Convolutional neural networks (CNNs) have led to a major advance in machine-based object classification performance and are sometimes described as approaching near-human levels of recognition accuracy. CNNs are also of great interest because they provide a biologically plausible model of object recognition; however, to what extent does their performance resemble that of human observers? The goal of this study was to evaluate the similarity and robustness of human and CNN performance, by presenting objects under challenging viewing conditions with varying levels of visual white noise. For the CNN, we relied on the AlexNet model (Krizhevsky et al., 2012) and images obtained from the 2012 ImageNet Large Scale Visual Recognition Competition. We pre-selected 16 out of the 1000 object categories (i.e., 8 animate and 8 inanimate categories) to compare performance across man and machine. Participants were briefly presented with each of 800 object images just once, at a randomly determined signal-to-noise ratio (SNR), and asked to identify which of the 16 categories was shown. To compare human and CNN performance, we normalized and fitted the performance data using a modified sigmoid function to determine the threshold SNR needed to obtain 50% accuracy at this identification task. Human observers required ~25% signal in the images to reach threshold levels of recognition accuracy, while AlexNet required greater than 60% signal on average. Moreover, humans were generally better at recognizing inanimate than animate objects, while the CNN showed no clear categorical advantage. These results suggest that human recognition is much more robust to visual noise than current CNNs, and that people may be able to infer diagnostic features of objects at much lower levels of SNR.

43.3047 Of Human Observers and Deep Neural Networks: A Detailed Psychophysical Comparison

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Deep Neural Networks (DNNs) have recently been put forward as computational models for feedforward processing in the human and monkey ventral streams. Not only do they achieve human-level performance in image classification tasks, recent studies also found striking similarities between DNNs and ventral stream processing systems in terms of the learned representations (e.g. Cadieu et al., 2014, PLOS Comput. Biol.) or the spatial and temporal stages of processing (Cichy et al., 2016, arXiv). In order to obtain a more precise understanding of the similarities and differences between current DNNs and the human visual system, we here investigate how classification accuracies depend on image properties such as colour, contrast, the amount of additive visual noise, as well as on image distortions resulting from the Eidolon Factory. We report results from a series of image classification (object recognition) experiments on both human observers and three DNNs (AlexNet, VGG-16, GoogLeNet). We used experimental conditions favouring single-fixation, purely feedforward processing in human observers (short presentation time of t = 200 ms followed by a high contrast mask); additionally, we used exactly the same images from 16 basic level categories for human observers and DNNs. Under non-manipulated conditions we find that DNNs indeed outperformed human observers (96.2% correct versus 88.5%; colour, full-contrast, noise-free images). However, human observers clearly outperformed DNNs for all of the image degrading manipulations: most strikingly, DNN performance severely breaks down with even small quantities of visual random noise. Our findings reinforce how robust the human visual system is against various image degradations, and indicate that there may still be marked differences in the way the human visual system and the three tested DNNs process visual information. We discuss which differences between known properties of the early and higher visual system and DNNs may be responsible for the behavioural discrepancies we find.

43.3048 Superstitious perception by humans and convolutional neural networks

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Recent comparisons between convolutional neural networks (CNNs) trained to identify objects in images and the human visual system have suggested that the hierarchical nature of the two systems is quite similar (Cichy, Khosla, Pantazis, Torralba, & Oliva, 2016), and that activity in higher order areas of the CNN predicts activity in infero-temporal cortex (Yamins et al., 2014). However, systematic behavioural comparisons of CNNs and human vision are just beginning. Our approach is to use the well-studied domain of visual illusions, where humans make predictable “errors,” to see if CNNs are governed by the same functional principles. We began with the phenomenon of superstitious perception (Gosselin & Schyns, 2003). Participants (n= 8) tried to identify targets in visual noise (total trials ~= 22,000), sometimes falsely selecting images as targets. Taking the average of the images identified falsely in this way results in a composite image resembling the target. We then compared two different methods for predicting which images were falsely identified. The first technique used the image-wise correlation between the target and the noisy image (Gosselin & Schyns, 2003), and it was able to discriminate participants’ “target present” responses from “target absent” responses significantly with d-prime = 0.10, 95% CI = [0.074,0.13]. The second technique used the likelihood of target reports generated by CNNs trained to identify noisy images of the target to increasing levels of accuracy. In contrast to a naïve, untrained CNN, which showed no measureable sensitivity, CNNs trained to identify real targets hidden in visual noise were able to discriminate participants’ responses with similar accuracy to image-wise correlation, d-prime = 0.10, 95% CI = [0.074,0.13]. While this implies that CNNs and humans use similar criteria for image identification, finer grained comparisons of the two methods also hint at important differences. These differences will be pursued in further experiments.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

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43.3049 Eccentricity Dependent Deep Neural Networks for Modeling Human Vision

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We introduce a computational model of the feedforward neural processing of a single glance of the human visual system. The model is based on deep neural networks and it builds on the invariant theory, which postulates mechanisms for invariant object representation in the human brain. Our model accounts for a diverse set of psychophysical phenomena related to object recognition. This allows to unify models of different visual mechanisms. These include invariant representations of objects, the acuity dependence with eccentricity, and crowding. We evaluate our model in the task of digit recognition using MNIST dataset. The experiments demonstrate that our model predicts the accuracy of the human visual system for recognizing digits in a flash, even in the presence of clutter. Furthermore, the results suggest that the human ability of learning new visual objects from few examples lies in the capacity of the brain to compute invariant representations of such objects with respect to geometrical transformations.

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43.3050 Map-CNN: A Convolutional Neural Network with Map-like Organizations

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Deep convolutional neural networks (CNNs) are currently the best computational models of visual processing. A core operation of these models is convolution: each artificial neuron of a CNN performs a sweep through the entire input image to produce a response profile. In contrast, neurons in the visual cortex have receptive fields, which are tuned to particular features at particular locations, though a common assumption is that a small set of features are replicated in hypercolumns uniformly across all positions in the retinotopic map. Here we examined this assumption using a computational model with map-like early layers. We constructed a map-CNN in which the artificial neurons in the map layer have a spatial organization and receptive field scaling similar to human V1. First, retinotopy was implemented with local convolutions of unshared weights, with neurons organized in a grid-like layout. Second, a retina-like transformation to the input image was applied, such that images are compressed with increasing distance from the center. The combination of these designs naturally captures both cortical magnification of the fovea and the receptive field size scaling with eccentricity. Finally, the network was trained on 1000-way object classification using the ImageNet dataset. We found that the features learned at each position of the visual field were not uniform, violating the convolutional assumption about the features represented across the visual field. Explorations of these tunings show that foveal map units (< 5°) had more gaussian-blob tuning than peripheral map units, and that while edge filters were learned uniformly across the visual field, the orientations of those edge features exhibited substantial positional biases. These results demonstrate that features learned from natural image statistics in order to perform successful object recognition are naturally heterogeneous across the visual field, and make testable predictions for the spatial distribution of feature tuning in retinotopic areas.

Acknowledgement: Star Family Challenge Award

PERCEPTION AND ACTION: MANUAL INTERCEPTION AND REACHING MOVEMENTS

Monday, May 22, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4001 Eye movements when the target that you want to intercept might bounce

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When trying to intercept a target that is moving along a straight path or flying through the air, people tend to follow it with their eyes throughout its motion. If the target is clearly going to bounce before reaching them, as it often does in cricket, (table) tennis or squash, people tend to make a saccade to a position close to which the target will bounce and to pursue it again from there. Presumably, it is important to be looking at the target as one approaches it, and the eyes cannot accurately follow the abrupt change in the target's motion when it bounces, so the eyes move in a manner that enhances pursuit after the bounce. We wondered whether finding out that an approaching target is going to bounce when it is already on its way is enough for people to adjust their eye movements to the fact that its motion will change abruptly when it bounces, or whether they can only make such anticipatory adjustments if they know in advance that the target will bounce. To find out, we conducted two experiments in which some moving targets bounced 500 ms after they appeared, and others did not. In one experiment it was impossible to predict whether an individual target would bounce off a visible structure or keep moving in a straight line. In the other experiment targets that would bounce were red whereas ones that would not were blue. We found that participants used the fact that they could anticipate the approaching target's behavior in the second experiment to alter their gaze strategy. Their eyes followed the target more closely near the time of the bounce when they knew that the target would bounce. We conclude that visual information can quickly guide strategic eye movements

43.4002 EYE-HAND COORDINATION IN INTERCEPTION WITH DELAYED VISUAL FEEDBACK

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When performing many common manual tasks, people's eye movements appear to be well coordinated with the movements of their hands. People readily learn to intercept a moving target with a cursor even if the cursor is delayed with respect to the hand by about 200ms. With such a delay, the position of the cursor is dissociated from that of the hand. We here examine how such adaptation influences eye-hand coordination. We recorded eye movements while subjects tried to intercept targets that were moving in different directions at different velocities. The experiment had 4 phases that differed in the feedback that was provided about the on-going movement of the hand. In the first phase they had full vision of the hand. In the second phase they had no visual information about the hand's movement. In the third (adaptation) phase they saw a cursor representing the hand. The fourth phase was identical to the second. During the adaptation phase we increased the delay between the hand and the cursor by 1ms on each trial until the delay was 200ms. When subjects could see their hand they hit the target with their hand. When feedback was removed they intercepted the target's path about 100ms ahead of the target. When a cursor represented the hand, they hit the target with the cursor, despite the delay, so that for large delays the hand passed even further ahead of the target. When the cursor was removed the hand gradually returned to crossing the target's path about 100ms before the target. In all cases the eyes simply pursued the target. In the adaptation phase the eyes continued to follow the target after the hand had crossed its path, presumably to obtain accurate feedback about the outcome of the movement.

43.4003 Both visual tracking and manual control performance predict infield batting accuracy in professional baseball players

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Professional baseball batters have less than 500ms to make a swing yet they manage to contact the ball most of the time. Here we examined whether baseball players have superior visual tracking and manual control capabilities and how they relate to real-world batting. First, we tested professional baseball players from Hong Kong leagues (n=44, 27 females) and demographically-matched non-athletes (n=47, 27 females) using a visual tracking task in which participants visually tracked step-ramp motion that varied unpredictably from trial to trial (speed: 16°/s-24°/s; direction: 0°-360°). Next, we used a manual control task in which participants used a joystick to center a randomly-moving (horizontal sum-of-sines motion: 0.1–2.19Hz) target. Last, to test whether visual tracking and manual control performance predict batting performance, we measured infield batting for a subset of players (n=23, all females, 3-18 years' experience). For visual tracking, baseball players showed shorter initiation latency, higher smooth-pursuit gain, and better speed-tuning and direction-tuning than non-athletes ($t(89)\geq 2.94$, $p< 0.01$). For manual control, baseball players showed better control precision, higher response amplitude, and shorter delay than non-athletes ($t(88)\geq 6.31$, $p< 0.001$). Notably, baseball players' manual control precision, response amplitude, and delay were all significantly correlated with smooth-pursuit gain (Pearson's r: 0.33-0.48, $p< 0.05$) whereas no such correlations were observed in non-athletes. For infield batting, hitting showed a weak positive trend with smooth-pursuit gain and manual control precision; subdividing the players by experience (9 or more years) revealed strong correlation for more-experienced (Pearson's $r=0.68$, $p< 0.05$) but not less-experienced (Pearson's $r\leq 0.29$, $p\geq 0.45$) players. Our sample of professional baseball players showed superior visual tracking and manual control capabilities, as well as coordination between visual-manual capabilities absent in non-athletes. Our study provides the first evidence visual tracking and manual control performance predict batting for more-experienced but not less-experienced players, suggesting that real-world batting develops within visuomotor limits.

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43.4004 Eye movement signatures of decision making and hand movement accuracy in a go-no go manual interception task

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Hitting a baseball requires a two-stage decision: whether or not to swing, and when and where to hit. These decisions have to be made ultra-fast, in less than 400 ms, and before the entire trajectory of the ball can be viewed. Here we investigate the role of eye movements in sensorimotor decision-making and interception under uncertainty. We developed a go-no go manual interception task in which observers (n=26 varsity baseball players) tracked and predicted linear target trajectories shown briefly on a screen. In each trial, the trajectory either went through a designated strike box (hit) or past it (miss). Observers were instructed to intercept the target with their index finger in the strike box in hit trials, and to not move their hand in miss trials. Only the initial launch (100-300 ms) of the ball was shown, and balls moved at 36 or 40°/s. Eye and hand movements were recorded with a video-based eye tracker and magnetic hand tracker. Linear regression and random-forest models were used to relate movements of eye, hand, and decision performance. The decision whether or not to intercept was best predicted by smooth pursuit velocity during the earliest (open-loop) phase of the movement, possibly due to more reliable motion trajectory information as a consequence of accurate pursuit initiation. Hitting accuracy was best predicted by pursuit position error and velocity gain during the later (steady-state) phase. These findings indicate that different stages of task performance could be predicted by different pursuit measures. Interestingly, performance was significantly better for the fast speed (shorter decision time) as compared to slow speed, where players frequently intercepted too early. On-field baseball experience with fast-moving balls might affect performance, a conclusion supported by the finding that more experienced, senior players showed a stronger performance benefit at high speed than junior players.

43.4005 The relationship between baseline variability and adaptation to temporal delays in interception

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Recent research has cast doubts on the idea that movement variability should solely be seen as noise of the system added to the motor command. A study of Wu et al. (2014) suggests that high levels of motor variability might help adaptation to new environments. This idea is appealing, as it could explain individual differences in adaptation between subjects. Here we determine if the level of variability could also explain differences in adaptation to temporal delays in interception. More specifically, we are interested to see if there is a difference between the task-relevant and task-irrelevant dimension. Subjects performed reaching movements on a graphic tablet towards a target that was moving either from left to right,

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or from right to left with various speeds. Their hand was occluded from vision and their movement was represented by a red cursor. Subjects were instructed to intercept the target with their cursor. After a baseline of 80 trials, we introduced a temporal delay of the cursor of 50 ms during 40 trials. We measured baseline temporal variability in the x- and y-dimension during the movement, and total adaptation after the temporal perturbation. We found a significant positive correlation (r=0.56) between the baseline variability in the y-dimension and the total adaptation to the temporal perturbation. This relationship was not present for the variability in the x-dimension. The results suggest a positive role for task-relevant variability in total adaptation. A possible explanation could be an increased sensitivity to previously made errors as suggested by Herzfeld et al. (2014).

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43.4006 **Effects of aging on illusory target motion in a hitting task.** Alix de Dieuleveult[1,2](alix.dedieuleveult@tno.nl), Anne-Marie Brouwer[2], Petra Siemonsma[3,4], Jan van Erp[2,5], Eli Brenner[6]; [1]Predictive Health Technologies, TNO, Leiden, the Netherlands, [2]Perceptual and cognitive systems, TNO, Soesterberg, the Netherlands, [3]Thim van der Laan, University for Physiotherapy, Nieuwegein, the Netherlands, [4]University of Applied Sciences Leiden, Leiden, the Netherlands, [5]University of Twente, Enschede, the Netherlands, [6]Vrije Universiteit, Amsterdam, the Netherlands

Age-related changes in multisensory integration (MSI, brain integration of multiple unisensory signals) were investigated. Accurate MSI is a key component of successful aging and crucial to perform activities of daily living (ADLs). Previous research suggests that with aging, different sources of sensory information are not properly weighted anymore. Twenty healthy younger (YA, age 18-34) and twenty-four healthy older adults (OA, age 60-82) were asked to hit discs moving downwards on a screen with their index finger. Illusory direction of motion was included (moving a checkerboard-like background either to the left or right). The discs disappeared before the screen was reached. Experimental conditions were: sitting (baseline), standing on foam (balance task), and sitting while doing a cognitive dual task (counting task). Participants hit the disc more to the right for left background motion compared to right background motion, conforming the illusory effect. OA show a larger effect of the illusion compared to YA in the baseline and balance conditions (p=.036 and p=.047, respectively). The same tendency was shown in the counting condition. Overall, background motion had a greater influence on the counting condition compared to the other conditions (p=.005 for YA and p=.009 for OA). No significant differences were found for the summed reaction and movement time, and no correlations between hitting performance and results of clinical pretests were found. We conclude that OA are more affected by the background motion than YA, which supports the idea that OA do not weigh information properly. Our finding that a cognitive dual task increases the illusion effect in both groups of participants suggests that cognitive resources are required for proper weighting, which may be a problem for OA. Future research will include OA with ADLs difficulties in order to develop a toolkit for early detection of MSI problems in the elderly population.

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43.4007 **Aiming under risk in healthy aging** Matteo Valsecchi[1](matteo.valsecchi@psychol.uni-giessen.de), Jutta Billino[1], Karl Gegenfurtner[1]; [1]Department of General Psychology, Justus-Liebig-University Giessen

Healthy aging is associated with changes in multiple aspects of motor control and cognition. Specifically, older adults have been found to be excessively risk-averse in economic decision-making tasks, and less efficient and more dependent on visual feedback when executing rapid movements. In the present study we investigated the performance of younger (N=52, age 18-30) and older (N=34, age 62-77) adults in the aiming-under-risk task, which constitutes the motor analogue of a gambling task, and in which younger adults are known to be close to optimal. In each trial, the observers had to tap their index finger on a touch screen before a time deadline which was individually titrated. They tried to hit a target area, which was associated with monetary gains, while avoiding a nearby or partially overlapping penalty area, which was associated with variable money losses. The results indicated that older adults were as efficient as younger adults, both groups scoring at on average over 90% of the gains expected from an optimal observer. Their strategies however differed. Younger adults tended to adjust their aiming points to avoid the penalty area slightly less than expected from an optimal participant, whereas the older adults showed a tendency for overadjustment. A model-based analysis of the aiming points as a function of penalty value, distance between penalty and target areas and observer precision, showed that the older adults´ strategy was compatible with a relative increase of the value attributed to losses relative to gains, compared to younger adults. Individual precision instead was not differently estimated by the members of the two groups. Overall, the results suggest that older adults are more risk-averse than younger adults in the aiming-under-risk task, similar to what has been shown for economic decision-making. At the same time, the change in strategy does not necessarily cause suboptimal performance.

43.4008 **Inefficient trade-offs of visual and motor information during time-limited movements in childhood** Imogen Large[1](i.large@ucl.ac.uk), Grace Sutton[1], Tessa Dekker[1]; [1]University College London

Visuomotor abilities, such as crossing a busy road or intercepting a ball, continue to improve until late childhood - but what drives these improvements is unclear. We tested whether development of visuomotor skill in childhood might in part be explained by improvements in the ability to account for visual and motor uncertainty. 6 to 10-year-olds and adults performed a time-limited rapid reaching task. In the main task, participants had to locate a hidden target within a set time (2s). Every 0.1s a dot would appear, randomly drawn from a bivariate Gaussian distribution centred on the target, until a reach was initiated. Participants were divided into two groups, one receiving a smaller distribution of dots (reliable cues), and one a larger distribution (unreliable cues). To maximise their score, subjects had to minimise the variance of their endpoint reaches around the target by trading-off time spent sampling visual information about the target's location, and time spent moving to 'catch' it. As such they had to trade-off between visual and motor uncertainty. To estimate each individual's gain-maximising (ideal) strategy, we also measured variance in (a) visual localisation and (b) movement precision for all possible sampling vs. movement time trade-offs. The trade-off at which total visuomotor variance was lowest was taken as their ideal strategy. While adults' sampling/movement times matched the ideal strategy in both visual cue-reliability conditions, young children consistently moved before gathering sufficient visual information. This is in line with previous studies suggesting that unlike adults, children are more likely to follow fast, 'risk-seeking' visuomotor strategies at cost to their performance (Dekker & Nardini, 2016; Jones, et al., in prep), rather than weighting visual and motor information appropriately.

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43.4009 **Visual Vector Inversion Contributes to the Coding of Reaching Movements Via Visuoperceptual Networks** Joseph Manzone[1](jmanzone@uwo.ca), Matthew Heath[1,2]; [1]School of Kinesiology, Western University, [2]Graduate Program in Neuroscience, Western University

Antipointing (i.e., reaching mirror symmetrical to a stimulus) requires top-down executive control to inhibit a pre-potent response (i.e., response suppression) and remap a target's visual coordinates (180° spatial transformation: i.e., visual vector inversion). Notably, antipointing displays an under- and overshooting bias for responses in the left and right visual fields, respectively. This visual-field specific endpoint bias demonstrates that antipointing is mediated via the same relative visual cues as perceptual judgments (i.e., via ventral visuoperceptual networks) (Maraj and Heath 2010: Exp Brain Res). It is, however, important to recognize that other reaching responses involving decoupled stimulus-response (SR) relations (i.e., reaching to a spatial location parallel to a target) have been shown to be mediated via absolute visual information (Thaler and Goodale 2011: Front Hum Neurosci). The present work sought to determine whether the top-down demands of SR decoupling (i.e., vector inversion and parallel remapping of target coordinates) are sensitive to target-based perceptual asymmetries. Participants performed target directed (i.e., propointing) and antipointing movements to targets in left and right space and responses were performed in conditions wherein the movement and target vectors were overlapping or parallel (i.e., in the parallel condition the target was 10 cm above the required movement vector). Importantly, for overlapping and parallel conditions participants fixated on a central cross and performed reaching movements along the same horizontal axis to ensure that responses were biomechanically equivalent. Results indicated that reaction time and endpoint variability was greater for the antipointing and parallel reaching conditions. Most interestingly, anti-, but not propointing, displayed a visual-field specific pattern of endpoint bias regardless of whether responses were completed in overlapping or parallel conditions. Thus, results demonstrate that the top-down demands of vector inversion results in a movement plan that is supported via relative and perception-based visual information.

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43.4010 **No Evidence that Binocular Vision Enhances Online Corrections for Reaches in the Lower-Visual Field** Jennifer Campbell[1](jcamp82@uwo.ca), Matthew Heath[1,2], Stephanie Rossit[3]; [1]School of Kinesiology, Western University, [2]Graduate Program in Neuroscience, Western University, [3]School of Psychology, University of East Anglia

The superior hemiretina contains a greater density of retinal ganglion cells than the inferior. Prior work has proposed a link between this vertical retinal asymmetry and the increased effectiveness of reaching movements performed in the lower-visual field (loVF, i.e., projecting to the superior hemiretina) when compared to their upper-visual field (upVF) counterparts (Rossit et al., 2013). In turn, reaches guided by binocular vision are more accurate than their monocular counterparts and is a result attributed to binocular cues optimizing response planning and online limb corrections. The goal of the present study was to examine whether putative differences in loVF and upVF reaches are influenced by the presence of binocular visual cues during movement planning and control. Participants completed reaching responses to illuminated targets positioned in the 3D picture plane. Participants fixated on one of two different locations allowing targets to be presented in the loVF and upVF. Separate groups of participants were provided vision during response planning and control (i.e., closed-loop condition: CL), or during response planning only (i.e., open-loop condition: OL). Both groups completed binocular and monocular vision trials. As expected, CL reaches and binocular trials were more accurate than OL reaches and monocular trials, respectively. Detailed analyses of reaching trajectories (i.e., 10% through 100% of MT) indicated that CL binocular trials produced greater spatial variability in the primary movement axis than CL monocular trials or OL (i.e., binocular or monocular) trials. However, our results did not yield evidence that trajectory control was influenced by our visual field manipulation (i.e., null main effects and interactions, all Fs < 1). Accordingly, our results provide no evidence that binocular cues optimize a vertical visual field asymmetry for online trajectory amendments.

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Face Perception: Emotion

Monday, May 22, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4011 **Sensory Reliability Does Not Alter the Weight of Visual information in Multisensory Emotion Adaptation** Ka Lon Sou[1](k-sou001@e.ntu.edu.sg), Fun Lau[2], Hong Xu[1]; [1]Division of Psychology, School of Humanities and Social Sciences, Nanyang Technological University, Singapore , [2]Neurolinguistics & Cognitive Neuroscience Lab, Division of Linguistics and Multilingual Studies, Nanyang Technological University, Singapore

Multisensory information is suggested to be integrated based on reliability-based model. Recently, it was suggested that perception and adaptation may be underlying different processes. Multisensory adaptation may follow a different integration model. The current study, therefore, investigates the possible integration models that explain audiovisual integration in multisensory emotion adaptation. Eighteen participants were tested in a 2-alternative forced choice adaptation paradigm. On each trial, the adaptor was shown for 3 seconds, followed by an emotion judgment task on a face morphed between happy and angry expressions. The noise information in visual adaptors was manipulated: the facial emotion recognition rate under noise was 60% - 80% as determined in a pre-experiment block. There were six conditions in the main experiment: 3 Unisensory conditions (with Auditory/Clear Visual/Noisy Visual adaptor), 2 Multisensory conditions (with Auditory with Clear Visual/Noisy Visual adaptor), and the baseline (no adaptor). All adaptors depicted anger emotion. Except for the auditory adaptor, all the other 4 adaptors (including the Noisy Visual) generated significant facial emotion aftereffects. By comparing the Bayesian Information Criteria of the three multisensory models obtained from within-subject multiple linear regressions (BIC visual-dominant = -130.299; BIC fixed-ratio = -136.125; BIC reliability-based = -130.740), our results suggested that multisensory emotion adaptation is best explained by the fixed-ratio model, with visual input contributing 62.8% regardless of the presence of the visual noise, Est./S.E. = 5.081, $p < .001$. Our findings indicated that in emotion adaptation, the multisensory percept is a weighted sum of the visual input and the auditory input, but the values of the weights are not determined by the reliability of the source of information. This is in contrast with multisensory emotion perception. We discuss the possibility that, on top of the perception of emotion, neural areas that are responsible for higher level executive functions are also adapted during multisensory adaptation.

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43.4012 **Neurodynamics of expression coding in human fusiform** Yuanning Li[1,2,3](ynli@cmu.edu), Michael Ward[3], Witold Lipski[3], R. Richardson[2,3], Avniel Ghuman[1,2,3]; [1]Program in Neural Computation, Carnegie Mellon University, [2]Center for the Neural Basis of Cognition, Carnegie Mellon University and University of Pittsburgh, [3]Department of Neurological Surgery, School of Medicine, University of Pittsburgh

Face processing is mediated by a network involving multiple distributed areas in the brain, with the occipital face area (OFA), fusiform face area (FFA), and posterior superior temporal sulcus (pSTS) considered the core nodes of the network. Results suggest that OFA is primarily involved in early perception of facial features, FFA is mainly involved in the processing of the static aspects of faces, and pSTS is mainly involved in the processing of the dynamic aspects of faces. Based on these results, the first models of the neural basis of face processing posited that pSTS codes for expression and FFA codes for identity. Recently, several neuroimaging studies have suggested that the FFA is involved in the processing of facial expressions and recent models have posited that the FFA is involved in structural encoding of face expression. To mediate between these hypotheses, we recorded intracranial electroencephalography (iEEG) data from 19 patients with electrodes in the OFA, FFA, and/or pSTS during face expression perception. Using pattern classification techniques, our results confirmed the existence of facial expression encoding in the fusiform area. At the early stage of visual information processing (100-250 ms after stimulus onset), neural activity from posterior fusiform area contains facial expression information; and at the late stage of visual processing (250-450 ms after stimulus onset), neural activity from anterior fusiform area contains facial expression information. In addition, facial expression information is seen in OFA and pSTS at the early stage of the process. Notably, the effect size of fusiform encoding of facial expressions is much smaller than the encoding for facial identity. Taken together, these results suggest that fusiform activity may contribute to the representation of the structural difference between facial expressions, and the posterior and anterior fusiform are dynamically involved in distinct stages of facial information processing.

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43.4013 **Detecting Emotional Facial Expressions in the Peripheral Visual Field: Psychophysical and Electrophysiological Evidence** Andrew Mienaltowski[1](andrew.mienaltowski@wku.edu), Hayley Lambert[1], Connor Rogers[1], Brittany Groh[1], J. Farley Norman[1]; [1]Department of Psychological Sciences, Ogden College of Science and Engineering, Western Kentucky University

Emotion detection requires one to recognize the presence of facial cues that signal a target's specific emotional state. The salience of facial cues is influenced by where in the visual field a facial stimulus is presented. Emotion detection should be superior in the center of a participant's visual field than in the periphery because retinal cone density is at its peak. The current study examined younger adults' ability to detect emotion on facial stimuli presented briefly at one of five horizontal locations on a display, -20, -10, 0, +10, +20 degrees from center. Participants completed two emotion detection tasks, detecting angry and happy expressions amongst neutral ones in separate blocks. Overall, there were 960 trials (480 per task, 96 at each location). Concurrently, visually-evoked potentials were recorded using a 128-channel high-density electrode array and were time-locked to the visual onset of the facial stimuli. The psychophysical data show superior detection ability for happy relative to angry expressions at each stimulus location, and that peripheral detection dropped off more sharply for angry than for happy expressions. Analyses also revealed that stimulus location impacted the visually-evoked N170 measured over occipito-temporal electrodes. Peak N170 amplitude was greater for centrally presented faces than for peripherally presented ones. Additionally, greater amplitude N170s were elicited in the hemisphere contralateral to the visual field in which the stimuli were presented. Follow-up analyses exploring the impact of expressive intensity on emotion detection demonstrated greater differences in detection performance for lower and higher intensity angry expressions than for lower and higher intensity happy expressions. Additionally, the difference in emotional versus neutral peak N170 amplitude was significant for high intensity emotional expressions but not for less intense emotional expressions.

43.4014 The "Just Noticeable Difference" in Threatening and Friendly Male and Female Faces

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Introduction: The just-noticeable difference (JND) has been used in psychophysics for over a century to determine the minimum threshold required to detect a change between two stimuli. However, little work has examined the JND for assessing sensitivity to changes in social stimuli. Here we attempt to characterize the JNDs at which a neutral face becomes expressive. We hypothesized that expression would interact with sex/gender; specifically, that happy and fearful expressions on females, and angry expressions on males, would have lower JNDs (i.e., a more precise visual discrimination) than opposite pairings due to sex/gender stereotypes for each expression, respectively. Methods: We used an adaptive staircase paradigm to locate the JND between a neutral face and target expressions (anger, fear, joy). Each trial in the staircase procedure consisted of an actor's neutral face displayed randomly in the LVF or RVF, along with a morph of the same actor expressing an emotion in the opposite VF at an intensity determined by the staircase procedure. Results: Male faces consistently had a JND that was lower than female faces. There was also an actor sex/gender by emotion interaction. Consistent with our hypothesis, female happy expressions had a lower JND than male happy expressions. However, both fear (stereotypically feminine) and anger (stereotypically masculine) expressions were lower for male rather than female faces, suggesting that the present results cannot be attributed entirely to stereotype congruency. Conclusion: Given the obtained results, the happiness advantage witnessed for female faces might be linked to a decreased salience of negative emotions and increased salience of positive emotions in female, but not male, faces. These results suggest an evaluative, rather than a stereotypic, happiness advantage for female faces (Hugenberg & Sczesny, 2006). Our findings offer one mechanism to help elucidate previous findings showing increased attention to female happy expressions.

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43.4015 Groups are more likely than individuals to be categorized as angry

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Groups are critical to human survival, allowing for greater collective access to resources and protection. Yet groups can also inflict harm, and miscategorizing the affect of a group can be costly. Judgments about whether a group is friendly or hostile are thus of great importance; they shape how people then interact with that group, regardless of whether those attributions are accurate. Since groups are more capable of inflicting harm than individuals, the potential cost of mislabeling a group's emotion should be greater than that of mislabeling the emotion of an individual. Extrapolating upon error management theory (EMT), we reasoned that it would be advantageous for people to engage a bias to categorize groups as "angry." Specifically, we expected that when making rapid decisions about groups' facial expressions, people would engage a bias to report the presence of anger. Additionally, we predicted that this bias would be amplified in the face of higher uncertainty about the group's emotion. Our results supported both of these predictions. Eighty-two observers viewed a single face or a group of 12 faces for 100-msec and indicated whether the face or faces were angry or happy. A signal detection analysis revealed that observers were biased to report the presence of anger. Importantly, this bias was amplified in response to groups compared to single faces. This was especially strong when the expressions of emotion were lowest in intensity, and therefore more ambiguous. Crucially, this bias occurred despite greater perceptual sensitivity to the actual expressions of groups compared to individuals, confirmed by modeling using probability summation. Our findings are consistent with EMT, which suggests that people may make biased attributions so that, if in error, they come at minimal cost. Compared to individuals, groups pose a compounded threat, and may therefore be more likely to be categorized as angry.

43.4016 Emotional face perception and spatial frequency

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Previous studies using human face stimuli have revealed differences in their detectability and saliency when certain emotions are exhibited. Some of these studies have suggested that different spatial frequency bands are important for the recognition and classification of those emotions; however there is no universal agreement on which subsets of spatial frequencies, if any, are vital for emotional face classification. Many of these studies have been limited by the number of emotions examined or by their methods, for example, pitting one emotional state directly against another. In the present study we employed stimuli that contained twenty-four different emotional states from the McGill Face Database (affectionate, alarmed, amused, baffled, comforting, contented, convinced, depressed, entertained, fantasizing, fearful, flirtatious, friendly, hateful, hostile, joking, panicked, playful, puzzled, reflective, relaxed, satisfied, terrified and threatening). These faces were presented, randomly interleaved, either in their entirety or after the removal of their low or high spatial frequency content, in a novel, subjective, emotion classification task. The task required observers to "point-and-click" the location within a 2-dimentional emotion space whose axes represented perceived arousal level vs. valance (pleasant vs. unpleasant), no non-semantic processing of emotion names was required. Using spatial statistics we compared the 2-dimentional distributions per emotion and per frequently condition. The analysis indicated that different emotions were consistently classified across the entire space independent of spatial frequency content, both within and between observers. Hence, based on these data we conclude that both high and low spatial frequencies can be utilized when identifying and classifying the emotional state of a face.

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43.4017 Spatial frequency utilization during the recognition of static, dynamic and dynamic random facial expressions.

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Previous studies have revealed that dynamic facial expressions (DFE) are better recognized than static facial expressions (SFE; Ambada et al., 2005). We have recently demonstrated that DFE can be recognized while fixating less on the features, and relying more on lower spatial frequencies (SF), than with SFE (Saumure et al., VSS2016). Since biological motion can be processed in extrafoveal vision (Gurnsey et al., 2008), the information provided by the motion in DFE may decrease the need to fixate the features and extract higher SF. This hypothesis would predict for dynamic-random facial expressions (D-RFE) created by altering the biological motion of the original DFE (i.e randomized frames) to be processed similarly to SFE. In this experiment, SF utilization of 27 participants was measured with SFE, DFE and D-RFE using SF Bubbles (Willenbockel et al., 2010). Participants categorized pictures and videos (block design) of the six basic facial expressions and neutrality, presented for a duration of 450 ms. SF tunings were obtained by conducting a multiple regression analysis on the SF filters and accuracies across trials. Statistical thresholds were found with the Stat4Ci (Chauvin et al., 2005). SF bands peaking at 16.6 cycles per face (cpf), 14 cpf, and 15.6 cpf were found with SFE, DFE and D-RFE, respectively (ZCrit=2.84,

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p< 0.05). Low SFs (3.2 to 4.2 cpf) were significantly more utilized with D-RFE than with SFE; and mid-to-high SFs (>18.6; 18.9 to 36.8 cpf) were significantly more utilized with SFE than with D-RFE and DFE respectively (ZCrit=3.09, p< 0.025). A marginal trend also indicated a higher utilization of low SF with DFE than with SFE (Zdynamic-static=2.57). These results suggest reliance on lower SF even when biological motion was altered.

43.4018 Similar visual strategies are used to recognize spontaneous and posed facial expressions Camille Saumure[1](sauc14@uqo.ca), Marie-Pier Plouffe-Demers[1], Daniel Fiset[1], Caroline Blais[1]; [1]Département de psychoéducation et psychologie, Université du Québec en Outaouais

Most studies bearing on the visual strategies underlying facial expression recognition have been done using posed expressions (PE). However, evidence suggests that these expressions differ from spontaneous expressions (SE) in terms of appearance, at least in regard of intensity (Ekman & Friesen, 1969), and facial asymmetry (Ross & Pulusu, 2013). In this experiment, the Bubbles method (Gosselin & Schyns, 2001) was used to compare the facial features used to recognize both kinds of expressions. Twenty participants were asked to categorize SE and PE of four basic emotions (disgust, happiness, surprise, sadness). Pictures consisted of 21 identities taken from the MUG database (Aifanti et al., 2010). The amount of facial information needed to reach an accuracy rate of 63% was higher with SE (M=64.0, SD=15.6) than with PE (M=34.4, SD=8.7) [t(19)=-15.07, p< 0.001], indicating that SE were harder to recognize. Classification images of the facial features used by participants to recognize each emotion were generated separately for SE and PE. Statistical thresholds were found with the Stat4CI (Chauvin et al, 2005; Zcrit=3.0; p< 0.025). Similar features were used for the recognition of SE and PE of disgust, happiness and surprise, although the Z scores reached significantly higher values with PE. With the expression of sadness, the information contained in the eye region was only useful for PE. An ideal observer analysis confirmed that the most diagnostic features in the recognition of happiness, surprise and disgust are very similar for PE and SE, and that the eye area has a lower diagnosticity in spontaneous sadness. These results suggest that the facial features utilization underlying the recognition of SE and PE is very similar for most basic expressions, although some qualitative differences are observed for the expression of sadness.

43.4019 Do Snapchat filters change how we perceive facial expressions? Jennifer Day[1](jeaday@ucsc.edu), Nicolas Davidenko[1]; [1]University of California, Santa Cruz

Snapchat is a social media application that allows users to take and send photos. It boasts 58.6 million users and has become one of the top used applications for millennials. Snapchat takes advantage of facial recognition algorithms to create and add filters to photos. Filters in this context are defined as digital additions or manipulations to photos, such as changing images to black and white or adding a rainbow in the foreground. In the following study, we studied how the choice of a snapchat filter influences perception of expression on that face. Subjects viewed face stimuli for 500 milliseconds and were asked to identify the expression. There were three possible filter states: fire filter, rainbow filter, or no filter. The expected valence of these filters was crossed with three types of expression: anger, happiness, and neutral. We compared whether different filters affected the perceived expressions in congruent (filter and expression matched) and incongruent (filter and expression mismatched) images. We found the number of correct responses to be significantly higher in congruent (versus incongruent) conditions, t(16) = 4.59, p < .001, and this was driven primarily by greater errors for angry expressions in the context of the rainbow filter. When the expression was happy we saw no effect of filter; however when the expression was angry we found the fire filter increased the likeliness people would rate the face as angry. For neutral expressions we found the presence of an active filter reduced accuracy, but not necessarily toward the filter. We observed no significant difference in reaction times. This study suggests filters can affect how we perceive expressions, which implies that these modified images are being perceived differently than original photos. More research about the contextual elements of expression needs to be done in the context of digital media.

43.4020 Temporal Examination of Age-Related Differences in Visually Evoked Potential to Onset of Emotional Facial Expressions Allison Rinne[1](allison.rinne334@topper.wku.edu), Nicole Chambers[2], Andrew Mienaltowski[1]; [1]Department of Psychological Sciences, Ogden College of Science and Engineering, Western Kentucky University, [2]Department of Psychology, Harpur College of Arts and Sciences,Binghampton University

Emotional expressions on face stimuli impact ERP components associated with visual perception and with goals for emotion processing. In younger adults, emotional expressions elicit larger peak voltage amplitudes for P1 and N170 over posterior electrodes and larger average voltages for EPN and LPC measured over posterior and centro-parietal electrodes, respectively. However, it is unclear if emotional expressions elicit similar enhancements for older adults. From a perceptual standpoint, emotion detection rules do not change with age. However, from a motivational standpoint, younger and older adults hold different goals for reacting to negativity. Consequently, patterns of brain activity may be age-dependent if divergent top-down goals moderate emotion perception. The current study investigated how neurocorrelates of emotion perception differ between older and younger adults at different times post-stimulus onset. Participants were presented with images of angry, happy, and neutral faces. ERPs were recorded using a 128-channel high-density electrode array and were time-locked to the visual onset of the faces. All participants displayed a larger amplitude N170 over occipito-temporal electrodes for emotional expressions relative to neutral; however, from 160-220 ms, older adults displayed a greater fronto-central positivity than did younger adults for emotional expressions. From 150-300 ms, both age groups continued to display greater emotion-related activation at posterior electrodes. From 220-300 ms, differential patterns of activity at parieto-central electrodes emerged. Relative to older adults, younger adults displayed a larger difference between angry and neutral expressions than between happy and neutral. This also was found from 300-800 ms over parieto-central electrodes. Overall, younger and older adults' visual systems display similar responses to emotional expressions, with emotional cues enhancing perceptual processing. However, from early on after stimulus onset until late in the epoch, there may be a dampening of older adults' reactivity to emotional expressions, especially negative ones.

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43.4021 Ensemble representation for multiple facial expressions: Evidence for a capacity limited but asymmetrical perceptual process between positive and negative facial expressions Luyan Ji[1](Luyan.ji@ugent.be), Gilles Pourtois[1]; [1]Department of Experimental-Clinical and Health Psychology, Ghent University

We have the ability to extract mean emotion from multiple faces. However, the boundaries of multiple facial expression processing are largely unknown. In this study, we tested the processing capacity of mean emotion representation by using the simultaneous-sequential paradigm. In Experiment 1, each set consisted of 16 faces conveying a variable amount of happy and angry expressions and was presented for 500ms. Participants were asked to judge on a continuous scale the perceived average emotion intensity from each set. In the simultaneous condition, the 16 faces were presented concurrently; in the sequential condition, two sets containing each 8 faces were presented successively. We found that average emotion judgments varied parametrically with changes in the happy vs. angry faces ratio. In addition, performance in the sequential was better than in the simultaneous condition, revealing a limited-capacity processing. Experiment 2 was the same as Experiment 1, except that different stimulus displays were used. Either happy and neutral, or angry and neutral expressions made up the face sets. The results confirmed that the average emotion judgments were sensitive to the emotional content of the face sets. However, the averaging process turned out to be qualitatively different between these two opposite emotions. Whereas it was clearly capacity-limited for happy faces (as found in Experiment 1), there was no significant difference between the sequential and simultaneous conditions for angry faces, suggesting unlimited capacities. Interestingly, post-experiment ratings showed that neutral faces were perceived as slightly negative. Altogether, these findings suggest that averaging multiple facial expressions is best conceived as a capacity-limited perceptual process. However, an asymmetry between positive and nega-

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tive facial expressions can be observed, with the latter emotion facilitating the rapid averaging process, presumably given its enhanced motivational significance for the organism and/or the reduced inter-stimulus variability along the valence dimension.

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43.4022 **Eye Left the Right Face: The Impact of Central Attentional Resource Modulation on Visual Strategies During Facial Expression Categorization**

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The categorization of facial expressions is impaired when central attentional resources are shared with an overlapping task (Tomasik et al., 2009). Using the psychological refractory period (PRP) dual-task paradigm, we verified if unavailability of central resources precludes the utilization of normal visual strategies. Twenty subjects took part in the study. In the first task (T1), they categorized a sound (150ms) as either low (200Hz or 400Hz) or high (800Hz or 1,600Hz) frequency. In the second task (T2), participants categorized the facial expressions of anger, disgust, fear, happiness, sadness, and surprise taken from the Karolinska face database (Lundqvist, Flykt & Öhman, 1998). External facial cues were hidden with an oval that blended with the background. Faces were sampled with Bubbles (Gosselin & Schyns, 2001) and presented for 150ms. T1 and T2 presentation was separated by a stimulus onset asynchrony (SOA) of either 300ms (central resource overlap) or 1,000ms (no overlap). Participants were instructed to answer as rapidly and as accurately as possible to both tasks, and not to wait for T2 onset before answering to T1. We performed a linear regression of Bubbles' coordinates on T2 performance. Statistical significance was determined with the Stat4CI toolbox (Chauvin et al., 2005). The categorization of angry, sad, fearful, and surprised expressions strongly correlated with utilization of both eyes and the mouth, at short and long SOAs ($Z> 3.4$, $p< .05$). Utilization of the left eye, however, was significantly reduced at short, relative to long SOA ($Z> 2$, $k> 2,347$ pixels, $p< .05$). Interestingly, whereas participants showed a bias favoring the left side of the face at long SOA, they favored the right side at short SOA. Participants always fixated the center of face stimuli. Thus, these results could be hinting at hemispheric differences in sensitivity to the modulation of central attentional resources.

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43.4023 **Trait anxiety moderates visual pathway contributions to the processing of clear versus ambiguous threat.**

Reginald Adams, Jr.[1](rba10@psu.edu), Hee Yeon Im[2,3], Noreen Ward[2], Jasmine Boshyan[2,3], Cody Cushing[2], Kestutis Kveraga[2,3]; [1]Department of Psychology, The Pennsylvania State University, State College, PA, U.S.A. , [2]Athinoula A. Martinos Center, Department of Radiology, Massachusetts General Hospital, Charlestown, MA, U.S.A., [3]Department of Radiology, Harvard Medical School, Boston, MA, U.S.A.

Introduction: Fear expressions combined with averted gaze clearly signal where threat resides. Fear expressions coupled with direct gaze, however, are more ambiguous. Supporting this contention, Adams and Kleck (2003) found that direct gaze facilitated processing efficiency, accuracy, and perceived intensity of averted versus direct gaze fear expressions. Amygdalar responses have also been found to be greater to clear threat when rapidly presented (300 ms) and to ambiguous threat for more sustained presentations (1 s; Adams et al., 2012). Similar flips in responses have been reported as a function of anxiety (Ewbank et al., 2010). Herein, we focus on differential contributions of the magnocellular (M) and parvocellular (P) pathways, and the moderating role of trait anxiety on neural responses to threat. Methods: Participants (N=108) viewed images of fearful or neutral faces with direct and averted gaze for 1 second presentations while undergoing fMRI. These stimuli were presented in high luminance contrast (Unbiased), low luminance contrast (M-biased), or isoluminant red/green (P-biased) images. Results: M-Clear threat cues yielded relatively greater activation in parietal and prefrontal regions along the dorsal visual stream, whereas M-Ambiguous threat cues evoked little activation. Conversely, P-Ambiguous threat cues yielded relatively greater activation in the occipital and inferior temporal regions along the ventral visual stream and the left amygdala. ROI analyses revealed that M-clear threat cues evoked greater right amygdala activation, whereas P-ambiguous threat cues evoked greater left amygdala activation, with high- versus low trait anxiety subjects showing the greatest increase to both. Conclusion: These findings suggest a differential visual pathway contribution to the perception of clear vs. ambiguous facial threat cues. Critically, these effects were moderated by perceivers' trait anxiety levels, reflecting heightened vigilance to threat, in both the M and P visual streams, to clear- versus ambiguous-threat cues, respectively.

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43.4024 **Hypersensitivity to low intensity fearful faces in autism when fixation is constrained to the eyes**

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Previous studies that showed decreased social brain activation in people with Autism Spectrum Disorder (ASD) viewing expressive faces did not control that participants looked in the eye region. This is problematic because ASD is characterized by abnormal attention to the eyes. In this study, we investigated social brain activation to expressive faces when fixation was maintained in the eyes. Functional magnetic resonance imaging (fMRI) data were collected from 48 male participants (27 with ASD) viewing pictures of neutral faces and faces expressing anger, happiness, and fear at low and high intensity, with a fixation cross between the eyes. We examined group differences in whole brain activity for the contrasts fear vs. neutral, anger vs. neutral and happiness vs. neutral at high and low intensity. We also investigated group differences in neural activity in regions of interest within the social brain, including the fusiform face area (FFA), the amygdala and the ventromedial prefrontal cortex (vmPFC). For the contrast fear vs. neutral at low intensity, we found that ASD participants had more activation in the social brain than controls, and less functional coupling between the amygdala and the vmPFC than controls. We also replicated previous results and found that activation in the FFA was similar in participants with and without ASD. Our results suggest that individuals with ASD are hypersensitive to low intensity fearful faces when they look in the eyes. We speculate that this indicates an excitatory/inhibitory imbalance in their socio-affective processing system, with ASD participants being over-aroused when looking at distressed emotional faces, while lacking emotional regulation capacities. In real life, this could result in social disengagement and avoidance of eye-contact to handle feelings of overarousal. Our results also highlight the importance of carefully controlling the gaze of participants in experiments addressing neurophysiological correlates of emotional processing in ASD.

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Face Perception: Social cognition

Monday, May 22, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4025 **Mapping Dynamic Conversational Facial Expressions Across Cultures**

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Conversational facial expressions are the most pervasive forms of facial expressions in real social contexts (e.g., Rozin & Cohen, 2003), and used to manipulate the flow of conversation – for example, showing encouragement can extend interactions, whereas showing doubtful can re-route or terminate it. Although conversational facial expressions play a central role in human-human interaction (e.g., Bavelas & Chovil, 2000; Chovil, 1991) and human-robot interaction (e.g., Cassell, 2000), comparatively little is known about their face movement patterns, and whether these patterns are similar across cultures (but see also Ekman, 1979; Nusseck, Cunningham, Wallraven, & Bülthoff, 2008). Here, we address this knowledge gap by modelling 50+ dynamic conversational facial expressions in two cultures (54 Western, 58 East Asian observers) using a facial expression generator (Yu, Garrod, & Schyns, 2012), reverse correlation (Ahumada & Lovell, 1971) and subjective perception (see also Gill, Garrod, Jack, & Schyns, 2014; R. E. Jack, Garrod, & Schyns, 2014; R. E. Jack, Garrod, Yu, Caldara, & Schyns, 2012). Cross-cultural comparison of the resulting dynamic facial expression models showed clear cultural similarities in facial expressions such as contented, offended, and sorry that correspond to culturally common facial expressions of emotion (see R. Jack, Sun, Delis, Garrod, & Schyns, 2016). In contrast, facial expressions such as doubtful, sympathetic, and indecisive showed culture-specific accents. Together, our results enhance knowledge of conversational facial expressions, and anticipate their application in informing the design of culturally aware digital economy technologies, such as social robots (e.g., Foster et al., 2012) and virtual humans (e.g., Swartout et al., 2006) to support the evolving communication needs of modern society.

43.4026 Cultural differences in face scanning during live face-to-face interactions using head-mounted eye-tracking

Jennifer Haensel[1](jhaens01@mail.bbk.ac.uk), Tim Smith[1], Atsushi Senju[1]; [1]Department of Psychological Sciences, Birkbeck, University of London

Eye-tracking studies have demonstrated cultural differences in face scanning strategies, with Western Caucasians (WC) showing triangular scanning patterns (eyes and mouth) and Eastern Asians (EA) exhibiting central fixations (Blais et al., 2008). However, as previous studies have been restricted to screen-based paradigms, it is unclear whether findings generalise to naturalistic settings. The present study used head-mounted eye-tracking to examine cultural differences in face scanning during live dyadic interactions, separated into periods of speaking and listening. Twenty EA and 20 WC dyads introduced themselves and played a story-telling task. We developed semi-automatic tools that dynamically track regions of interest (ROI; upper/lower face) and classify gaze points accordingly. Results revealed that both groups showed significantly more face gaze when listening than when speaking. Cultural differences were observed during speaking, with increased face gaze at the listening partner in EA compared to WC participants. Contrary to predictions, no group differences were found for duration of upper gaze scanning, or duration and frequency of mutual gaze, questioning the notion of gaze avoidance in EA observers (Argyle et al., 1986). We also employed a data-driven approach whereby face regions and gaze points are mapped into a normalised space to generate difference maps of gaze density. Initial results revealed that EA observers, relative to WC participants, showed more central gaze (between the eyes). WC observers, meanwhile, showed greater left-side bias and gazed more at the eyes and nose when listening, and the left eye and mouth when speaking. Forthcoming spatial density analysis will statistically examine cultural differences in gaze distribution. Overall, these findings indicate greater gaze distribution in WC participants and more localised eye scanning in EA observers. This replicates screen-based studies using emotionally expressive faces (Jack et al., 2009; Senju et al., 2013) and demonstrates cultural differences in naturalistic face scanning for the first time.

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43.4027 Spatial frequencies for rapid and accurate race categorisation in Caucasian participants

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Race categorisation is faster for other race (OR) than same race (SR) faces (Caldara et al., 2004). Some researchers propose that face identification prevails for SR (but not for OR faces), thus decreasing race categorisation proficiency for their own-race (Hugenberg et al., 2010). To gain a better understanding of this phenomenon, we investigated the perceptual basis of race categorisation. Sixteen Caucasians were asked to categorize rapidly and correctly the race of 50 Caucasian and 50 Afro-american faces (400 trials per race). On each trial, the spatial frequencies (SF) of the stimuli were randomly sampled using SF Bubbles (Willenbockel et al., 2010). Small amounts of white noise were added to each stimulus to keep accuracy at ~90%. Multiple regression analyses were conducted on the sampled SFs and the participant's speed (using a median split) to create group SF classification images (CI) for Caucasian and Afro-american faces separately. SFs between 1.7 and 9.3 cycles per face (cpf; peaking at 3.4 cpf; peaks were calculated using a 50% area spatial frequency measure) were significantly correlated with response speed for Caucasian faces, whereas SFs between 4.3 and 23.7 cpf (peaking at 10.3 cpf) were significantly correlated with response speed for Afro-american faces. Subtracting one CI from the other showed that rapid categorisation with Caucasian faces was significantly more correlated with the availability of low SF (< 3.3 cpf); $Z_{crit}=3.45$, $p< 0.025$) whereas medium/high SF availability lead to fast categorisation with afro-american faces (between 8.3 and 34.7 cpf); $Z_{crit}=3.45$, $p< 0.025$). These results demonstrate that participants categorized SR faces rapidly if the SFs important for face identification (i.e. medium SFs) were removed from the stimulus, whereas rapid OR face categorization can be based on medium SFs.

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43.4028 Learning to see faces like humans: modeling the social dimensions of faces

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The human perceptual system can make complex inferences on faces, ranging from the objective evaluations regarding gender, ethnicity, expression, age, identity, etc. to subjective judgments on facial attractiveness, trustworthiness, sociability, friendliness, etc. Whereas the objective aspects have been extensively studied, less attention has been paid to modeling the subjective perception of faces. Here, we adapt 6 state-of-the-art neural networks pretrained on various image tasks (object classification, face identification, face localization) to predict human ratings on 40 social judgments of faces in the 10k US Adult Face Database. Supervised ridge regression on PCA of the conv5 2 layer in VGG-16 network gives best predictions on the average human ratings. Human group agreement was evaluated by repeatedly randomly splitting the raters into two halves for each face, and calculating the Pearson correlation between the two sets of averaged ratings. Due to this methodology, the models correlations with the average human ratings can exceed this score. We find that 1) model performance grows as the consensus on a face trait increases, and 2) model correlations are always higher than human correlations with each other. These results illustrate the learnability of the subjective perception of faces, especially when there is consensus, and the striking versatility and transferability of representations learned for object recognition. This work has strong applications to social robotics, allowing robots to infer human judgments of each other.

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43.4029 Social Inclusion and the Perception of Animacy in a Face

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Introduction: Previous work has reported the breaking point for perceiving animacy in a doll face morphed with a human face is around 70% on the continuum toward being more doll like (Looser & Wheatley 2010). Other work has shown that social rejection, manipulated via the classic cyberball task (Hartgenrink et al., 2015) influences how we perceive faces (Berstein et al., 2010). Herein, we combined these techniques to examine whether the experience of social rejection/inclusion influences the perception of animacy in a face. We predicted that social rejection would make participants sensitive to humanness in the face, thereby lowering the threshold more for when doll-like features are perceived as life like. Methods: Participants (N = 65) completed the cyberball task, and were randomly assigned to the inclusion versus exclusion condition. A control group (N = 41) completed this same task without going through the cyberball task. Next, they were given arrays of 50 morphed faces varying in 2% increments linearly from a human to a doll face. Their instructions were to choose the point at which the face began to appear less human than doll like. Results: Contrary to our predictions, social rejection did not change perceptions of animacy when compared to the control group. We did find that social inclusion significantly shifted the threshold of perceiving animacy in a face to later

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in the continuum (i.e., more doll like), both compared to the control t(1, 19) = 39.04, p < .001) and social exclusion group t(1, 19) = -2.86 p < .007). Critically, no other studies using the cyberball task to our knowledge have reported effects due to the social inclusion. Conclusion: This work suggests social inclusion can have a meaningful influence on face perception, in this case on the perception of animacy in the human face.

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43.4030 Narrow boundaries for categorization of the identity of personally familiar faces

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Faces of personally familiar individuals are represented in a view invariant manner in the brain. Changes in viewpoint, age, and distance, as well as impoverished viewing conditions do not affect recognition of familiar faces as much as they affect unfamiliar faces. However, fine tuning of the face processing network to familiar faces might not allow similarly invariant behavioral responses to changes identity specific features. We hypothesized that the categorical boundary for identifying images of a familiar face may be narrower than categorical boundaries for unfamiliar face images. We used a continuum of morphs between familiar and unfamiliar faces to find the threshold at which a stimulus was categorized as the familiar face. As a control, we used a continuum of morphs between two unfamiliar faces to find the threshold at which one unfamiliar face was distinguished from another. We analyzed categorical perception curves for unfamiliar-familiar morphs and unfamiliar-unfamiliar morphs, by comparing the frequency of identity judgments for each level of morphing. We also analyzed the reaction times in the experimental and control conditions. Our results indicated slower response times when the morphed stimuli were drawn from unfamiliar-familiar continuum as compared to the unfamiliar-unfamiliar continuum. More interestingly, we found that the morph percentage threshold for reporting a stimulus as familiar was closer to the familiar face end of the morph continuum than the unfamiliar face end, suggesting lower tolerance for deviation from a familiar identity. This indicates that subjects use a more conservative threshold for categorizing the identity of a familiar face than when categorizing the identity of an unfamiliar face. These results suggest that the face identification system is more finely tuned to familiar faces and less tolerant of changes to their features.

43.4031 Ensemble Representation of Facial Attractiveness Adaptation by Rapid Serial Visual Presentation

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Facial attractiveness is one of the most important facial characteristics. Recent evidence suggests that our visual system is able to interpret facial expressions from multiple faces presented temporally via ensemble statistics. Does our visual system perceive facial attractiveness in the same way? Here we used a visual adaptation paradigm (adapted from our previous study in ensemble statistics of facial expressions) to investigate how we perceive facial attractiveness from a rapid serial visual presentation (RSVP) of various faces. Levels of facial attractiveness in the faces were assessed pre-test. In the current study, subjects were passively adapted to RSVPs of faces (42.5 Hz) or their statistically averaged, static counterpart, and were then asked to judge a subsequently presented test face as either attractive or unattractive. We compared the aftereffects generated by the RSVPs of attractive faces and their statistically averaged face. Results showed that the RSVP of attractive faces (M = 16.20%, SEM = .022; t(28) = - 7.30, p < .001) and the paired averaged face (M = 15.65%, SEM = .018; t(28) = - 6.14, p < .001) both induced significant facial attractiveness aftereffects, and there was no significant difference between them (t(28) = .278, p = .783). Also, there was a significant positive correlation between the aftereffects of the attractive RSVP face stream and its average attractive static face (r = .66, p < .001). Our results suggest that the visual system interprets facial attractiveness from rapidly presented faces by ensemble representation, and sheds light on our understanding of the mechanisms of face perception.

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43.4032 The Female Cambridge Face Memory Test (F-CFMT+)

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The Cambridge Face Memory Test (CFMT1) is a validated test of unfamiliar face recognition that is widely used. A longer form of the task (CFMT+) was developed to evaluate individual differences in face recognition abilities2. Both tasks were designed to include adult male face stimuli exclusively in order to avoid inducing potential sex differences in face recognition, which are disproportionately reported during recognition of female faces3. As a result, studies employing the CFMT/CFMT+ are limited to conclusions about male face recognition. However, questions regarding sex differences in face recognition behavior and potential own-sex biases in patterns of recognition are re-emerging in the literature. Therefore, an analogous version of the CFMT with female faces is necessary to evaluate potential sex differences and biases in face recognition behavior. We created a comparable female face version of the CFMT/CFMT+ that is matched in number of trials, blocks, and parameters as the original task. It also includes a 4th block, which is much more difficult than the first three blocks (as in the male version of the CFMT+) to test individual differences. To evaluate the validity, consistency, and internal reliability of the F-CFMT+, we compared the performance of 149 young adults on the short and long forms of our newly-created F-CFMT+ with the M-CFMT+. We found that: a) performance on the F-CFMT+ was highly correlated with performance on the M-CFMT+, b) there was comparable inter-block reliability within the F-CMFT+ as compared to the M-CFMT+, and c) there was a comparable range of individual differences on the two tasks. One important difference is that participants were more accurate overall on the F-CFMT+. Ongoing development of the task will resolve these differences prior to its release for research purposes. 1 Duchaine & Nakayama, 2006, 2 Russell et al. 2009, 3 Lewin & Herlitz, 2002

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43.4033 Visual representation of age groups as a function of ageism levels

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Prejudice against the elderly is a growing concern and has shown to report many negative social and individual consequences (European social survey, 2012). Last VSS (Dion-Marcoux et al., 2016), we presented a study showing that ageism modulates the mental representation of a prototypical young and old face: individuals with higher prejudice represented a young face as being older and an old face as being younger than individuals with less prejudice. The present study verified if this finding is subtended by ageism modifying the boundaries used to categorize a person as young or old, or by ageism modifying the representation of facial aging throughout life. Thirty young adults took part in three tasks: An Implicit Association Test, an age categorization task, and a Reverse Correlation task. In the Reverse Correlation task, participants had to decide which of three faces embedded in white noise was most prototypical of the appearance of a 20, 40, 60 or 80 years-old face (block design). The mental representations of the ten participants with the highest vs. lowest ageism were averaged, and presented to 30 individuals who estimated their age. Results show a significant interaction between ageism and face group on the perceived age [F(3, 87)=17.17, p< 0.05]. Although participants with higher prejudice had a significantly older perception of the age 40 [t(58)=3.077, p=0.0032], the pattern reversed for 80 years-old faces [t(58)=-2.317, p=0.024], which they represented as younger. The boundary used in the age categorization task did not differ as a function of ageism [t(18)=0.18, ns]. These results suggest that highly prejudiced individuals represent different groups (40, 60 and 80 years-old) of other-age faces as being less dissociable from one another than lower prejudice individuals.

43.4034 Perception of others' body sizes is predicted by own body size

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Previous research demonstrated that estimates of others' body sizes are biased towards the average body size in the population (Cornelissen, Gledhill, Cornelissen & Tovée, 2016). Bodies in the environment not only influence the internal reference of what is perceived as average or "normal", but also play an essential role in self-body size evaluation via social comparison (Cattarin, Thompson, Thomas & Williams, 2000). In two psychophysical experiments, we asked whether there is also an influence of own body size on the perception of others' body sizes. For Experiment 1, four biometric female avatars with a body mass index (BMI) of 15, 25, 35, and 45 were generated, and then their weight was altered (± 5, ±10, ±15, and ±20% BMI change) based on a statistical body model. For each of the avatar series, female participants spanning the BMI range memorized what the avatar's body looked like and then responded for the presented bodies varying in weight whether it was the same as the one memorized. Results showed no influence of participants' BMI on the accuracy of body size estimates, but sensitivity to weight changes was highest for bodies close to one's own BMI. In Experiment 2, we examined whether this effect was driven by memory or perceptual factors. Specifically, in a 2-alternative forced choice discrimination task, two bodies were presented simultaneously using the same BMI categories as in Experiment 1. If participants' body size influences sensitivity during simultaneous presentation, it would suggest that the effect found in Experiment 1 is not due to a better memorization of bodies that are close to one's own body size. Again, sensitivity to differences in body weight was highest for bodies close to one's own BMI. These results suggest that our own body size influences our perceptual ability to discriminate the sizes of other's bodies.

43.4035 Similar Neural Network Topology for Men and Women During Face Recognition

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There is renewed interest in evaluating the extent to which face processing and its underlying neural circuitry is sexually dimorphic. We recently found no sex differences in face recognition behavior (Motta-Mena et al., under review) or in patterns of neural activation during face recognition as determined using univariate voxelwise and ROI-based analyses (Scherf et al., under revision). However, it could still be the case that men and women exhibit different patterns of neural functional connectivity during face recognition. To examine this possibility, we investigated potential sex differences in the topology of directed functional neural connections within the face-processing network in typically developing young adults. Participants completed a recognition task in the scanner in which they had to identify both a male and a female target face among separate blocks of male and female distractor faces. Core and extended regions in the face-processing network were defined using a separate localizer task. Effective connectivity was modeled separately for males and females during recognition of male and female faces using unified SEM. We quantified potential differences in global network topology using graph theory and pattern recognition metrics. Both male and female participants modulated the topology of directed functional connections as they shifted between recognizing male and female faces. During female face recognition, female participants exhibited a homogenous and unique pattern of connections that were not shared by the male participants, whose networks were more heterogeneous. In contrast, there were no sex differences in the organization of network topology during recognition of male faces. In general, this pattern of results reflects similar topological organization and modulation of the face-processing network for men and women during face recognition, which is consistent with our previous findings from univariate analyses.

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43.4036 Evidence for face pareidolia in rhesus monkeys.

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In everyday life we have a tendency to see faces in non-face objects; a famous example is the face of a nondescript man on the surface of mars. Although these misperceptions are often very compelling, it is not known whether "face pareidolia" is unique to humans or whether it is an experience shared with other animals. Like humans, rhesus monkeys have a functionally defined face-processing system, comprised of multiple interconnected areas distributed along the ventral visual pathway. In this study, we reasoned that the potential analogy between this system and our own made it likely that rhesus monkeys also experience face pareidolia. To test this hypothesis, we first collected 15 examples of face pareidolia from the public domain together with objects matched for object-content. An additional 15 photographs were taken of unfamiliar rhesus monkey faces. All possible pairs of these 45 images were shown to 5 male rhesus monkeys, one at a time for 4 seconds, in a visual paired comparison task. We collected two dependent variables (the total amount of time spent looking at each image; first fixation in each trial). In addition to replicating the common observation that rhesus monkeys look longer at face stimuli than other kinds of objects, we also found clear evidence that monkeys look for longer periods of time (and first) at examples of face pareidolia than at object-matched control images. We repeated this experiment with the images inverted and collected independent data from human participants (N = 10) who were asked to rate how face-like each image was on a 200-point scale. Overall, our results indicate that monkeys also see face configurations in non-face objects and, as such, provide the first compelling evidence of face pareidolia in any species other than our own.

Acknowledgement: NIH intramural funding

43.4037 Discrimination of individual faces in visual cortex

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The ability to differentiate a particular face from others or to generalize faces to a common feature such as gender or race is critical for social interactions. Then, how is face information represented in the visual cortex when face individuation is emphasized compared to when face generalization is emphasized? To address this question, we performed a functional magnetic resonance imaging (fMRI) experiment, comprising two generalization tasks – gender and race tasks -, and one discrimination task – matching task. On each trial of every task, a participant saw a sample face image, followed by a test face image. In the gender task, participants were asked to decide whether the gender of the sample face image is the same with that of the test face image, while in the race task, they had to determine whether the sample face and the test face are from the same race category. In the matching task, the test image was a face fragment image, and they were instructed to decide whether the fragment image belonged to the sample face. We independently localized face-selective cortical areas, and compared decoding of individual faces from the multi-voxel pattern of response for the sample face perception in each task. In the gender or race task, the face-selective cortex did not show significantly distinct representations for each face. However, in the matching task, the response of face-selective cortex could be used to decode the individual face information. These results suggest that top-down signals modulate the cortical representation of individual faces during perception. This work was supported by a grant of the Korea Health Technology R&D Project through the Korea Health Industry Development Institute (KHIDI) funded by the Ministry of Health & Welfare, Republic of Korea (HI15C3175), and the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIP) (2016R1C1B2010726).

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VISUAL MEMORY: LIMITATIONS

Monday, May 22, 8:30 am - 12:30 pm

Poster Session, Pavilion

43.4038 A Shared Mechanism for Mnemonic Precision in Visual Short-term Memory and Visual Long-term Memory

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To efficiently interact with exceedingly rich contents in natural vision, it is important for observers to retain precise memory representations that closely correspond to external stimuli in both visual short-term memory (VSTM) and visual long-term memory (VLTM). Evidence from animal and human memory research indicates that VLTM precision is supported by hippocampal pattern separation, a computation that orthogonalizes similar memories into distinct representations such that precise VLTM is possible in the face of interference. However, it is unclear what mechanisms underlie VSTM precision. The present study examines whether mnemonic precision of both VSTM and VLTM is supported by hippocampal pattern separation. Using an individual differences approach, Experiment 1 (n = 52) obtained behavioral evidence that VSTM precision, VLTM precision, and pattern separation are related. Specifically, behavioral measures of VSTM precision from a short-term color recall task, VLTM precision from a long-term color recall task, and pattern separation performance from a mnemonic similarity task were significantly correlated with one another, suggesting large shared variance among these constructs. Using fMRI, Experiment 2 (n = 19) directly linked VSTM precision to hippocampal activities. In this experiment, different demands on mnemonic precision were introduced by asking participants to memorize 4 colors randomly sampled from a color wheel with 180 colors (high-precision), 15 color spokes (medium-precision), or 6 color spokes (low-precision) – and to recall one of the studied colors from a corresponding color wheel. By comparing BOLD signals across these three precision load conditions and a perceptual and motor control condition, we tracked brain activities that increased with VSTM precision load. Specifically, we found that BOLD signals in the left hippocampus changed as a function of VSTM precision load, along with the medial prefrontal cortex and bilateral angular gyrus. Altogether, these findings support a shared computational and neural mechanism for mnemonic precision of visual memories.

43.4039 Remembering stimuli in different depth planes increases visual working memory precision and reduces swap errors.

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If visual working memory performance depends on competition between similarly tuned neurons in visual cortex, two items with very dissimilar features should be easier to remember than two very similar items. Thus, remembering two items with different retinal disparities, as opposed to two items with the same disparity, should reduce competition between the items because each recruits a different set of binocularly-tuned neurons. Also, introducing depth information to mnemonic displays should reduce uncertainty about the location of a remembered item in depth and reduce confusion, or 'swap' errors. To test this general prediction, we conducted a visual working memory study using a stereo display. Subjects remembered the colors of two briefly presented (150ms) stimuli that were on the same or different depth planes and reported the color of a cued item after a 750ms delay by clicking a color wheel. A mixture model analysis revealed that different depth planes had a higher precision than those on the same depth planes ($p = 0.025$) than stimuli presented on the same depth plane. We also found significantly fewer swap errors when the remembered items were on different depth planes ($p=0.0147$), indicating less confusion between target and distractor occurred for stimuli that were more separable in depth. This supports the notion that working memory capacity is at least partly limited by competition between similarly tuned neurons. Furthermore, previously-observed limits in working memory performance can be mitigated by separating stimuli in the third dimension

43.4040 Visual Memory for Change Detection is Better with Gaze Shifts

Nicholas Kleene[1](nkleene88@gmail.com), Melchi Michel[1]; [1]Rutgers University

Estimating the capacity of visual short-term memory (VSTM) has been a rich topic of study. VSTM capacity is usually estimated using change detection or discrimination tasks, but these tasks rarely require participants to make eye-movements (saccades) as they would in the real world. Previously, we found greater memory capacity in a visual search task requiring eye-movements than a search task where gaze position is fixed, as in classical change detection and discrimination (Kleene & Michel, 2016). This result indicates that typical VSTM tasks may underestimate the capacity of visual memory. Therefore, we sought to estimate visual memory capacity in the presence and absence of eye-movements using two change discrimination tasks, one where participants could not move their eyes (gaze-fixed) and one where participants were required to make an eye-movement (gaze-shift). Participants were first presented with a memory display consisted of one, two, four or six oriented Gabors drawn from a Gaussian distribution with fixed variance. Participants then either maintained fixation (fixed-gaze) or made a 5° saccade (gaze-shift), while a mask was briefly flashed. A test display was then presented, consisting of a randomly-selected Gabor from the memory display that had been rotated. The task was to report whether the test Gabor had been rotated clockwise or counterclockwise from the memory display. Discrimination performance was used to estimate visual memory capacity was via three approaches: an information-theoretic model that quantifies memory capacity in terms of bits, a traditional continuous resource model that quantifies the fidelity of memory representations in terms of feature precision, and an item-limited discrete resource model that quantifies memory capacity in terms of number of items, or slots. Preliminary results indicate that, regardless of which measure is used, memory capacity is greater with than without a gaze shift.

43.4041 Visual Short-term Memory for Dynamically Changing Stimuli

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Laboratory research on Visual Short-term Memory (VSTM) often uses static stimuli, which is a great simplification of ever-changing stimuli in natural vision. It is unclear whether VSTM for dynamically changing information shows similar characteristics, such as limited storage capacity, as static stimuli. The present study assessed VSTM for continuously rotating stimuli using a delayed estimation task. In Experiment 1, participants memorized the orientation of a clock hand that continuously rotated clockwise or counterclockwise for 150 milliseconds under verbal suppression. Memory set sizes (1 versus 2 in Experiment 1A; 1 versus 3 in Experiment 1B) and the directions of rotation were randomly mixed across trials. After a 1000-ms retention interval, participants estimated the orientation of a randomly probed memory item, as accurately as possible, by clicking on the clock face. The distributions of orientation estimation errors were fit with the Zhang & Luck (2008) discrete slot model with an additional parameter (μ) representing the central tendency of the error distribution using maximum likelihood estimation and hierarchical Bayesian method. As set size increased, the precision of recalled memory representation decreased with a small increase in guessing rate, replicating some previous findings using static orientation stimulus. In addition, there were systematic shifts in memory representations that were in the directions of the clock hand rotation, indicating a lag between VSTM encoding and the onset of the stimulus. More interestingly, the shifts in μ were comparable across set sizes, providing preliminary support for parallel consolidation of VSTM representations. Experiment 2 replicated the shifts in μ using colors that continuously rotated in a circular color space. Additional control experiments ruled out some alternative accounts based on overall response biases and lack of sensitivity in the present method. Together, these results have provided some insights into VSTM for dynamic stimuli.

43.4042 Representation of Object Information during Associative Memory Retrieval

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Memory retrieval is thought to involve an interaction between a retrieval cue (or some elements of a memory) and a full memory trace. Memory models have proposed that the hippocampus plays a critical role in binding together the diverse elements of a memory, allowing holistic recollection of all elements. To investigate how the presented cue and the linked elements of a memory are represented in the hippocampus and cortical areas, we conducted an event-related functional magnetic resonance imaging (fMRI) experiment with a simple object association task. The task was comprised of separate learning and retrieval sessions. During the learning session, outside the scanner participants were trained to memorize object pairs for about one hour. During the retrieval session, one day after the learning session, participants were scanned, and instructed to see a cue object image (one of the learned objects), followed by a test phase. In the test phase, they were asked to decide whether the test object is paired with the cue object. Every participant showed good performance in the test (> 90% correct on average). Using multi-voxel pattern analysis, we found that during the presentation of a cue object, the response patterns of hippocampus showed greater similarity between paired objects compared to unpaired objects, while the response of object-selective visual cortex could be mainly used to decode the identity of the cue objects. These results suggest that hippocampal representation reflects integrative information of related objects even when incomplete information exists. This work was supported by a grant of the Korea Health Technology R&D Project through the Korea Health Industry Development Institute (KHIDI) funded by the Ministry of Health & Welfare, Republic of Korea (HI15C3175), and the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (2016R1C1B2010726).

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43.4043 **Protection against interference limits visual capacity to three items independent of retention interval** Hiroyuki Tsubomi[1](htsubomi@hmt.u-toyama.ac.jp), Keisuke Fukuda[2], Edward Vogel[3]; [1]University of Toyama, [2]University of Toronto Mississauga, [3]University of Chicago

The capacity of visual working memory is limited to representing three simple objects that no longer exists in the external environment. Interestingly, we previously found that this severe capacity limit also applies to representing objects that remained visible (Tsubomi, Fukuda, Watanabe, & Vogel, 2013). Here, we further investigated a critical factor that determines this capacity limit for representing visible and no-longer visible information. To do this, we asked participants to observe eight sample color squares for 1s and then tested their memory immediately or after a 1 second-long blank retention interval with a bicolor test probe providing two alternatives to choose from as the original sample color. Replicating our previous finding, three-item capacity limit was observed for both with and without retention interval. In the critical conditions, we cued the test location prior to the onset of the test probe using two types of cues with varying sample-to-cue ISIs. When a dot cue was presented, we found that the cuing effect was best observed when the cue was presented while the sample color squares were present, and this cueing effect gradually decreased over time after the sample squares disappeared. By contrast, when a color patch cue was presented, we did not observe reliable cuing benefit across all ISIs. These results indicate that the interference caused by the onset of the color patch cue or the bicolored test probe itself is a critical factor that limits visual capacity to three items independent of the retention interval. In other words, only a few object worth of visual information can be maintained robustly against the interference at a given moment regardless of whether the objects are present or not. Meanwhile, there is another type of large-capacity visual representations that are vulnerable to interference and decay over time after the objects disappear.

43.4044 **Processing Stage Affected by Visual Prediction is a Function of Preparation Time** Cybelle Smith[1](cmsmit13@illinois.edu), Kara Federmeier[1]; [1]Department of Psychology, University of Illinois at Urbana-Champaign

Preparatory preactivation of visual features has been shown to facilitate image processing using behavioral and neurophysiological measures. We explored how the amount of predictive preparation time (i.e., the time between display of a visual scene cue and its recently associated novel object target) would modulate the timing, nature and amount of visual processing facilitation at the target. We recorded EEG as 48 participants learned paired associations between visual scenes and novel objects from novel object categories. At test, participants indicated whether an object matched a previously viewed scene. Critically, at test, the scene was previewed for either 200ms (N=24) or 2500ms (N=24), prior to object onset. ERPs time-locked to object onset at test displayed a graded pattern of facilitation contingent on how closely the test object matched that presented with the scene at study. Critically, the time-course of this sensitivity varied with the amount of preview time, such that fine-grained distinctions based on object similarity and category structure were observed earlier in the long preview condition. With long previews, graded facilitations emerged during the N300 time window, as early as 200-300ms, suggesting that participants were able to anticipate structural features of the objects and object categories. Instead, when participants had little time to develop predictions, fine-grained distinctions emerged only later, beginning at ~300-400ms. In addition, a later positivity (400-600ms) exhibited a similar graded pattern of effects, and may reflect integrative processing used to assess the degree of match between the presented object and the scene. With short previews, this later positivity was numerically larger and exhibited a larger contrast between matching and mismatching objects. Our findings suggest that visual predictive preactivation percolates earlier in the visual processing stream when more time is available to generate a (more detailed) prediction.

43.4045 **Fluid and Adaptive Changes of Prospective Memory Control** Seth Koslov[1,3,4](koslov@utexas.edu), Jarrod Lewis-Peacock[1,2,3,4]; [1]Department of Psychology, University of Texas at Austin, [2]Department of Neuroscience, University of Texas at Austin, [3]Center for Learning and Memory, University of Texas at Austin, [4]Imaging Research Center, University of Texas at Austin

Prospective memory describes the ability of individuals to remember to perform goal-relevant actions in the future. The multiprocess view of prospective memory posits that two separable control processes underlie this ability: proactive control, which involves maintenance of goal information in working memory and monitoring of the environment for relevant cues to act; and reactive control, which involves the formation and automatic retrieval of cue-response associations from episodic memory to achieve goals. Previous research has demonstrated that individuals will engage proactive and reactive control strategies based on the demands of the task environment. Participants tend to rely on reactive control in situations with a high cognitive load, whereas proactive control is favored in situations with fewer cognitive demands. However, people don't always utilize the strategy best suited for a situation, which can lead to performance costs and memory failures. Being able to adaptively implement control strategies in response to changing task demands is important, but little is known about if and how people accomplish strategy flexibility. Here, we sought to characterize the dynamic adjustment of control strategies used for prospective remembering. Participants were asked to identify the reappearance of a picture target (a face or scene) while at the same time performing a visual search task. To bias strategy choices, we manipulated the attentional demands of the visual search task on a moment-to-moment basis using two metrics: target-to-distractor coherence and distractor variability. Behavioral results showed that a more difficult visual search task biased people towards reactive control, and a simpler visual search task biased them towards proactive control. Moreover, we found that people fluidly and incrementally shifted between control strategies in response to rapidly changing visual search demands. These results support a view of prospective memory in which the utilization of control strategy is highly flexible and adaptive to concurrent demands.

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43.4046 **Response priming reveals capacity limitations** Marjan Persuh[1](mpersuh@bmcc.cuny.edu), Bella Matias[2]; [1]Department of Social Sciences, Human Services and Criminal Justice, Borough of Manhattan Community College, City University of New York, [2]Department of Psychology, City College of New York, City University of New York

Visual working memory, a system for temporary storage and manipulation of visual information, is strictly limited in capacity. Similarly, humans' ability to track is limited to only a few individual items at a time. We hypothesized that there is a common source of these limitations. Our working hypothesis was that capacity limitations originate at the encoding stage and are a general property of the visual system. We tested our prediction using response priming, a paradigm that differs substantially from both working memory and object tracking paradigms. It requires fast motor responses and rapid processing of visual information. Evidence also suggests that response priming requires intact retinogeniculostriate pathway. We hypothesized that priming is limited by the representation of visual information at the encoding stage. We tested participants in two experiments; the first experiment presented bars of different orientations and second experiment used different shapes. Participants made speeded responses to targets displayed at the center of the display. Prior to target presentation, a prime was presented at one of the eight positions around the imaginary circle. We varied the number of items on the screen by presenting a single prime together with distractors. Priming effects were the strongest for a single prime, presented in isolation. As the number of distractors increased, priming effects become progressively weaker and with the set size of six, were eliminated altogether. These results suggest that the capacity of visual system to represent individual objects for priming is similar to restrictions previously demonstrated for working memory. Furthermore, because response priming is independent of visual awareness, our results indicate that capacity limitations of our visual systems are not restricted to conscious vision.

43.4047 Memory compression using statistical regularities requires explicit awareness

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Visual working memory (WM) is a core cognitive ability that predicts broader measures of cognitive ability. Thus, there has been much interest in the factors that can influence WM capacity. Brady, Konkle & Alvarez (2009) argued that statistical regularities may enable a larger number of items to be maintained in this online memory system. In a WM task that required recall of arrays of colors, they included a patterned condition in which specific colors were more likely to appear together. There was a robust improvement in recall performance in the patterned condition relative to one without the regularities, an effect that has been referred to as "memory compression". Brady et al suggested that this effect was a product of visual statistical learning, the ability to apprehend statistical relationships automatically and without reliance on explicit knowledge. This has been an influential finding, but it is inconsistent with multiple other studies that have found no benefit of exact repetitions of sample displays in similar working memory tasks (e.g., Olson and Jiang, 2004; Logie and Brockmole, 2009). What distinguishes the Brady et al. procedure from the others? Here, we offer a possible reconciliation of these findings. We replicated the benefit Brady et al. observed in the patterned condition, but we obtained a larger sample of subjects and included an explicit test of subjects' memory for the repeated pairs. Strikingly, memory compression effects were observed only in the subset of subjects who had perfect explicit recall of the color pairing at the end of the study. The remaining subjects showed no advantage in the patterned condition. These findings argue against the hypothesis that statistical regularities elicit automatic "compression" of multiple items in visual WM. Instead, the effect may be better understood as an example of paired associate learning.

43.4048 Longer Memory Delay Reveals Demands for Maintaining Multiple Features

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Interacting with real-word environments requires maintaining individual features and integrating them into a representation of a whole object. This requires encoding objects and their features as integrated wholes successfully into our visual short term memory (VSTM). Theories of VSTM suggest that remembering multiple features of an object does not require additional memory resources, but aging populations and Alzheimer's patients show specific deficits in maintaining bound objects. These processes could reflect impaired memory maintenance, but it is also possible that apparent memory deficits reflect perceptual and attention processes during encoding. To better understand the possible reasons for this discrepancy, we increased the maintenance demands on the VSTM system by increasing the memory delay in a change detection task. The increase in delay should indicate whether additional cognitive demands are needed to maintain two versus one feature objects. Subjects were run on a VSTM change detection task using both a 2000ms and 5000ms delay. On each trial, subjects were cued to detect a change in color, shape, or either. For the either cue, either color or shape could change. Our findings support the literature that indicates VSTM capacity is similar for single and two feature objects at shorter delays. However, we found a significant cost for remembering two features objects in the 5000ms delay. These results demonstrate that at longer memory delays VSTM for two-feature objects requires additional resources as compared to a single-feature condition. By taxing the maintenance demands of healthy individuals we can differentiate performance for single and two feature conditions. These findings offer a possible solution for the disparity of findings in healthy and clinical populations.

43.4049 Where do cognitive limitations come from and why do we care? The divergent cases of visual working memory storage and approximate number sense acuity

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At any given moment, the mind is constrained by certain fundamental limits. Research on Visual Working Memory (VWM) storage capacity and Approximate Number Sense (ANS) acuity has emphasized the identification of independent behavioral and neural signatures. But where do an individual's limits come from? Are they shaped by the same or different factors? And what relevance do these limits have - jointly or independently - for everyday life? Here, in a single sample of 430 monozygotic (MZ) and 238 dizygotic (DZ) twin individuals, we investigate heritability, age curves, and practical correlates for both VWM storage and ANS acuity. We intentionally designed our VWM storage and ANS acuity tasks to be perceptually identical on a moment-to-moment basis (indistinguishable over any 0.7 given second period), differing critically in their cognitive demands. Despite this task similarity, we found strikingly divergent results. First, VWM storage was highly (67%) heritable whereas ANS acuity was even more highly (100%) environmental, suggesting nearly independent etiological factors. Second, we found about a decade difference between the ages of peak performance: VWM storage peaked relatively early at age ~20, whereas ANS acuity peaked later at age ~30 (the latter is consistent with Halberda et al, 2011, PNAS). Third, while both measures were predictive of validated self-report measures of math and science skills, VWM storage was more predictive for both math skills, $R2=.07$, $F(1,666)=48.90$, $p< .001$, and science skills, $R2=.06$, $F(1,666)=38.72$, $p< .001$, compared to ANS acuity ($R2=.03$, $F(1,666)=23.52$, $p< .001$ and $R2=.02$, $F(1,666)=16.44$, $p< .001$, respectively). Moreover, most of the predictive power for VWM storage was independent of ANS accuracy, and (to a lesser extent) vice versa. These results suggest a strikingly independent story of etiological origins and everyday importance for two core cognitive limitations.

43.4050 Visual working memory representations bypass divisive normalization

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How distinct is visual working memory from visual perception? Although evidence suggests that briefly remembered stimuli are represented within early visual cortices, it remains unknown whether these visual memory traces undergo the same neural computations as true visual representations. Here, we examined whether visual memory representations succumb to a hallmark visual computation: divisive normalization. The strength of normalization was assessed during perception by utilizing a surround suppression paradigm wherein participants replicated the contrast of a center stimulus, which was enveloped by a full contrast surround. We measured perceived contrast for five contrast levels (10-75% contrast) by means of a method-of-adjustment task. Observers were presented with a center-surround stimulus and were asked after a 2s retention interval to use a dial to match the contrast held in memory. Results revealed substantial suppression of the apparent contrast across all contrast levels. Next, we moved the surround stimulus into the retention interval to test the degree to which a contrast memory representation can be influenced by a subsequently presented surrounding stimulus. If representations within visual working memory undergo normalization similarly to visual representations, the presence of the surrounding stimulus should attenuate the apparent contrast of the remembered stimulus, just as it would when center and surround stimuli are presented simultaneously. We quantified this by fitting

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perceived contrast estimates with the normalization model, and found evidence to the contrary: while the presence of the surround stimulus attenuated memory for the contrast of the remembered stimulus when they were presented simultaneously, the presence of the surround stimulus during the retention interval had no impact on the quality of visual memory, indicating a lack of contrast normalization between working memory stores. While visual memory representations may reside within early visual areas, they are qualitatively distinct from true visual representations, bypassing divisive normalization, a canonical visual computation.

43.4051 **Distinct memory processes for high- and low-capacity individuals beyond their memory capacity** Youngseon Shin[1](yshin2016@fau.edu), Summer Sheremata[1,2]; [1]Center for Complex Systems and Brain Sciences, Florida Atlantic University, [2]Department of Psychology, Florida Atlantic University

Visual short-term memory (VSTM) actively maintains visual information for ongoing tasks. However, the amount of visual information an individual can maintain, or capacity, is highly limited and varies between individuals. The performance of VSTM related task is near perfect up to an individual's VSTM capacity, and it drops as the number of items in the task increases. Here we report evidence supporting different patterns of memory performance between high and low memory capacity individuals above their capacity. In the first block, we measured memory capacity of individuals using a change detection task with set sizes based on each individual's Pashler's K in the following blocks: easy block: K-1, K, K+1, and difficult block: K+1, K+2, K+3. We found that both low- and high-capacity individuals reached plateau performance in the easy block. However only high capacity subjects sustained plateau performance in set sizes beyond their capacity. Low-capacity individuals are more susceptible to exceed the number of objects being held in the memory. The effect of set size above memory capacity indicates that memory performance at high set sizes is associated with distinct memory processes for high- and low-capacity individuals. Low capacity individuals are less able to ignore additional information and they might try to remember all of items resulting in poor memory representations at high set sizes

43.4052 **Fidelity of VSTM representations across the visual field reflects right-hemisphere specialization** Summer Sheremata[1](ssheremata@fau.edu), Sabrina Loftus[1,2]; [1]Department of Psychology, Florida Atlantic University, [2]Center for Complex Systems and Brain Sciences, Florida Atlantic University

Previous studies have demonstrated that hemispheric asymmetries in visual short-term memory (VSTM) processing give rise to differences in memory capacity across the visual field. However, correct performance on change detection tasks requires detecting large changes in stimuli and therefore cannot distinguish between two competing theories of the significance of these asymmetries. The first, the right-hemisphere specialization theory, states that the right-hemisphere allocates greater resources to remembering objects. This theory predicts greater precision for each object across set sizes in the left visual field. In contrast, the global processing theory suggests both hemispheres spread equal resources but the right hemisphere spreads them across a greater space or more objects, predicting equal or poorer precision for each object and decreasing precision as set size increases. By investigating the pattern of errors in VSTM, precision paradigms can measure the fidelity of each item held in memory and tease apart these two competing theories. We therefore performed a precision working memory task in which colored-squares were presented to either the left- or right- visual hemifield. The subjects were asked to report the color of a single cued square, by clicking a location on the color-wheel that represented the remembered color. Memory precision was measured for set sizes 3 and 4. There was greater precision in left visual field and no interaction with set size. Left-handed individuals did not show a consistent effect. Our findings demonstrate that the higher capacity for objects presented in the left visual hemifield occurs without a cost to the fidelity of the representation for each object. Together, these results link visual field asymmetries to a right-hemisphere specialization for VSTM processes.

43.4053 **Neural bases of automaticity** Mathieu Servant[1](servant.mathieu@gmail.com), Peter Cassey[2], Geoffrey Woodman[3], Gordon Logan[4]; [1]Department of Psychology, Vanderbilt University, [2]Department of Psychology, Vanderbilt University, [3]Department of Psychology, Vanderbilt University, [4]Department of Psychology, Vanderbilt University

Automaticity allows us to perform tasks in a fast, efficient, and effortless manner after sufficient practice. Theories of automaticity propose that across practice processing transitions from being controlled by working memory to being controlled by long-term memory retrieval. Recent event-related potential (ERP) studies have sought to test this prediction, however, these experiments did not use the canonical paradigms used to study automaticity. Specifically, automaticity is typically studied using practice regimes with consistent mapping between targets and distractors and spaced practice with individual targets, features that these previous studies lacked. The aim of the present work was to examine whether the practice-induced shift from working memory to long-term memory inferred from subjects' ERPs is observed under the conditions in which automaticity is traditionally studied. We found that to be the case in 3 experiments, firmly supporting the predictions of theories. In addition, we found that the temporal distribution of practice (massed versus spaced) modulates the shape of learning curves. The ERP data revealed that the switch to long-term memory is slower for spaced than massed practice, suggesting that memory systems are used in a strategic manner. This finding provides new constraints for theories of learning and automaticity.

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Visual Memory: Attention and cognition

Monday, May 22, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4054 **Sustained spatial attention is not sufficient to elicit the Contralateral Delay Activity** Nicole Hakim[1](nhakim@uchicago.edu), Kirsten Adam[1], Eren Gunseli[1], Edward Vogel[1]; [1]The University of Chicago

The Contralateral Delay Activity (CDA) is a popular neural measure used to track storage in visual Working Memory (WM). The amplitude of the CDA increases with the number of memoranda, asymptotes around 3 items, and is sensitive to individual differences in behavior. However, there is still debate about whether the CDA reflects WM contents or sustained spatial attention. WM tasks place high demands on sustained spatial attention, so attention and WM demands have been confounded in previous work. Here, we tested whether the CDA manifests when demands for sustained spatial attention are high, but demands for WM storage are absent. In the WM task, participants performed bilateral change detection for colored squares. In the attention task, participants had to continuously attend to locations that were previously occupied by squares and report the orientation of a rare target line during the blank period. Thus, the squares that served as memoranda in the WM condition, served as spatial cues indicating the likely position of the target in the attention condition. As expected, we found a large, sustained CDA during the WM task. Additionally, there was a set size effect for the WM task, with larger amplitude for set-size 4 than set-size 2. For the attention condition, by contrast, the CDA was entirely absent for both set sizes. In a follow-up experiment, which required finer spatial precision to discriminate the targets, there was also no evidence for the CDA during the attention task. However, during the attention task in each experiment, we observed a known marker of spatial attention (sustained contralateral alpha suppression), which provides positive evidence that subjects were indeed sustaining spatial attention throughout the trial. Given these results, we find no evidence that sustained spatial attention alone can drive the CDA, which supports claims that this activity reflects memory storage.

43.4055 **Attentional Mechanism for Organization in Visual Working Memory** Chengfeng Zhu[1,2](zhucf@zju.edu.cn), Shulin Chen[1], Rende Shui[1], Mowei Shen[1], Zaifeng Gao[1,2]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University, [2]Corresponding author: zhucf@zju.edu.cn zaifengg@zju.edu.cn

It has been suggested that visual working memory (VWM) is involved in integrating the sampled discrete information into a coherent visual percept. However, how this integration takes place in VWM for the sequentially processed information remains unclear. We recently demonstrated that VWM can realize and use potential Gestalt principles within the sequentially encoded representations: The closure and similarity cues among the sequentially presented objects significantly enhanced VWM performance relative to conditions without gestalt cues (Gao, Gao, Tang, Shui, & Shen, 2016, Organization principles in visual working memory: Evidence from sequential stimulus display. Cognition, 146, 277-288). In the current study, we examined (1) whether the VWM organization is an automatic process regardless of attention, (2) if VWM organization is a voluntary process, which type of attention plays a pivotal role. To this end, we displayed the to-be-memorized stimuli sequentially and in half of trials there were gestalt cues; critically, an attention-consuming task (visual search task for space-based attention or mental rotation task for object-based attention) was added into the maintenance phase of VWM. We predicted that if the VWM organization was an automatic process, the secondary task should affect the organization effect. If the VWM organization was a voluntary process, we predicted that the secondary task would erase the organization effect. Experiments 1 and 2 tested the role of attention underlying closure, and found that visual search task erased the organization effect while mental rotation task did not. Experiments 3 and 4 tested the role of attention underlying similarity, and found that mental rotation task erased the organization effect while visual search task did not. Together, we suggest that VWM organization is a voluntary process, yet the key attention is determined by the nature of the memorized stimuli.

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43.4056 **How Task Irrelevant Contents of VWM and LTM affect Attentional Guidance and Disengagement** Rebecca Goldstein[1](rebecca.r.goldstein@gmail.com), W. Joseph Delaune III[1], Melissa Beck[1]; [1]Louisiana State University

Task irrelevant information in visual working memory (VWM) may affect attention guidance and disengagement. The contents of VWM may capture attention during visual search with a long-term memory (LTM; Gunseli, Olivers, & Meeter, 2016) or VWM template (van Moorselaar, Theeuwes, & Olivers, 2014). In the current study, participants held a colored shape in VWM while searching for a rotated N among upright Ns placed upon colored shapes. One of the distractors was on a colored shape that matched the color, but not the shape, of the VWM item. In E1, a LTM target template was used (the target color was always the same). The color-matched distractor was rarely fixated, demonstrating that the contents of VWM do not necessarily guide attention. However, in E2 and E3, the target color was not known, and the color-matched distractor was fixated more than non-color match distractors. To test the effect of attending to task irrelevant information on attentional guidance and disengagement, the shape of the VWM color-matched distractor was the same on every training trial. Half the test trials included a distractor with the repeated shape, but not the VWM color (no-color-match repeated shape), and the other half were the same as the training trials (color-match repeated shape). The VWM task required memory for color only in E2 and memory for color and shape in E3. The no-color-match repeated shape distractor did not capture attention in E2 or E3. However, in E3, dwell times on the no-color-match repeated shape distractor were shorter compared to a random distractor. When the VWM task required memory for color and shape, the repeated shape was learned and affected attentional disengagement. Task irrelevant VWM contents guide attention when there is not a competing task relevant template, and this can lead to LTM task irrelevant information that affects attentional disengagement.

43.4057 **Object-based Attention Underlies the Storage of Event Files in Working Memory** Xiqian Lu[1](lu_xq@zju.edu.cn), Yangfan Zhao[1], Rende Shui[1], Mowei Shen[1], Zaifeng Gao[1]; [1]Department of Psychology□Zhejiang University

Processing events containing action-related information is vital to our daily activities such as action planning and social interaction. It has been suggested that during event process action-related information are bound with other visual elements (e.g., colors, locations) as event files. To form coherent experience of outer world and guide our social behavior, we have to retain event files in working memory (WM). In the current study we explored whether keeping event files in WM consumes more attention than keeping the constituent elements. Considering that object-based attention underlies the rehearsal of static feature bindings in WM, we hypothesized that object-based attention plays a key role in retaining event files in WM. As the most frequently seen event in daily life is biological motion (BM), the movements of animate entities, we therefore took BM related event files as the tested stimuli in our study (BM-color event files in Experiments 1 and 3; BM-location event files in Experiment 2). In separated blocks we required participants to memorize BM, colors (locations), or BM-color (locations) event file. Critically, we added a Duncan object-feature report task, which consumed object-based attention, into the maintenance phase of WM. We predicted that the added secondary task led to a larger impairment for BM event file than for the constituent elements. In congruent with this prediction, Experiments 1 and 2 consistently revealed a selective impairment to the BM event files. Moreover, this selective impairment was not due to the unbalanced number of elements between the event file condition and the single element conditions (Experiment 3). Taken together, these results suggest that object-based attention plays a pivotal role in maintaining event files in WM.

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43.4058 **Temporal-order-based attentional salience modulates visual working memory representations in the parietal cortex** Qing Yu[1](qyu55@wisc.edu), Won Mok Shim[2,3]; [1]Department of Psychiatry, University of Wisconsin-Madison, [2]Department of Biomedical Engineering, Sungkyunkwan University (SKKU), [3]Center for Neuroscience Imaging Research, Institute for Basic Science (IBS)

The respective roles of the occipital, parietal, and frontal cortices in visual working memory (VWM) maintenance have long been under debate. Considering the previous mixed findings on whether the multi-voxel response patterns in the parietal and frontal regions convey mnemonic information (e.g., Ester et al., 2015; Riggall & Postle, 2012), one possibility is that attentional salience based on temporal order can modulate the mnemonic signals in high-level frontoparietal regions. To test this hypothesis, we examined whether temporal recency could lead to changes in the mnemonic representations. On each trial, participants viewed two gratings with different orientations in succession, and were cued to remember one of them. After a long delay of 10.4 s, participants rotated a test grating until its orientation matched the remembered orientation. Using fMRI and a forward encoding technique (Brouwer & Heeger, 2009; 2011), we reconstructed population-level, orientation tuning responses in the occipital (V1-V3), parietal (IPS), and frontal (FEF) areas during VWM maintenance. Unlike the early visual cortex where robust tuning responses were observed regardless of whether the remembered target was the first or second in the sequence, the parietal and frontal cortices showed better tuning responses when participants remembered the second grating, indicating the effect of recency. To exclude the possibilities that this effect was caused by the residual perceptual or motor preparative signals elicited by the second grating, we conducted a control experiment where participants performed a change detection task on serially presented color patches that were masked by a colored pattern. The results again demonstrated superior representation for the color of the second patch in IPS, but at later time points during retention. These results suggest that attentional state, such as attentional salience brought by recency, has a strong influence on the mnemonic representations in the parietal cortex.

43.4059 **Action-related upating of visual working memory: Attentional weighting of spatial locations and feature dimensions** Anna Heuer[1](anna.heuer@uni-marburg.de), John Crawford[2,3,4], Anna Schubö[1]; [1]Experimental and Biological Psychology, Philipps-Universität Marburg, Marburg, Germany, [2]Centre for Vision Research, York University, Toronto, Ontario, Canada, [3]Department of Psychology, York University, Toronto, Ontario, Canada, [4]Canadian Action and Perception Network (CAPnet), York University, Toronto, Ontario, Canada

Visual working memory (VWM) contents can be weighted to reflect differences in task-relevance. This is typically studied by presenting retrocues during the retention interval, but under natural conditions, the relevance of visual objects is mostly determined by action intentions. In a series of experiments, we investigated whether actions induce a weighting of VWM representations according to action-relevance. This investigation built on two mechanisms of action-related selective processing that influence perception: The deployment of spatial attention to action goals, and the selective weighting of action-related feature dimensions. In a combined memory and movement task, participants memorized items and performed a movement during the retention interval. This was either a pointing movement towards a specific location, or a particular type of movement. In experiments with pointing, memory was better for test items presented at locations corresponding to the movement goal than at action-irrelevant locations. This preferential maintenance of action-relevant information was particularly pronounced when memory load was high. Performance at locations neighbouring to the movement goal was better than at locations farther away, indicating an attentional gradient spreading out from the action goal. Experiments with different types of movements showed that representations are also weighted to reflect the action-relevance of feature dimensions. Memory for items defined by size was better during the preparation of a grasping movement than during the preparation of a pointing movement. Conversely, memory for colour tended to be better when a pointing movement was being planned. Whereas size is a relevant feature dimension for grasping, colour can be used to localize a goal object and guide pointing. Taken together, these findings show that our actions modulate visual processing not only during perception, but also during short-term retention. This action-related updating optimizes the efficient use of capacity-limited VWM, and ensures that information required for upcoming actions is easily available.

43.4060 **The Effect of Emotion on Processing Distractor Items in a Visual Working Memory Task** Christine Salahub[1](cs13aj@brocku.ca), Stephen Emrich[1]; [1]Brock University

Emotion (whether positive or negative) has been found to influence both attention and memory-related processes. Xie and Zhang (2016) found that negative affect in particular increases the resolution of information that is stored in visual working memory (VWM). However, it remains unclear whether affect acts directly upon the quality of these representations, or if it instead impacts earlier attentional processes, such as attentional selection and breadth, which have been shown to be affected by affective states. The current study investigated the relationship between affect and attentional breadth by measuring the likelihood that nearby stimuli would influence a target judgment (i.e. non-target errors). Participants were first shown an image that was positive, negative, or neutral in valence on every trial. They then completed a continuous report VWM task wherein they remembered 2 or 4 colored shapes over a short delay, then recalled one shape's color from a color wheel. A three-component mixture model analysis (Bays, Catalao, & Husain, 2009) was used to estimate the proportion of target, non-target, and guess responses made in each condition. It was found that negative and positive affect differentially affected the likelihood of making non-target errors, such that less non-target errors were made in the negative affect condition. The present findings suggest that emotion influences attentional control, which is consistent with theories suggesting that VWM performance is linked to attentional selection during encoding.

43.4061 **When is reward-associated information prioritised in visual working memory?** Edwin Dalmaijer[1](edwin.dalmaijer@psy.ox.ac.uk), Claire Poullias[1], Rosyl Somai[1,2], Masud Husain[1,3]; [1]Department of Experimental Psychology, University of Oxford, [2]MSc programme in Neuroscience and Cognition, Utrecht University, [3]Nuffield Department of Clinical Neurosciences, University of Oxford

Visual Working Memory (VWM) is a highly limited resource that can be flexibly distributed over a limited number of items. Storing more items comes at the cost of a lower fidelity for individual items. Given this pressure on VWM resources, we hypothesised that they are biased to be distributed to behaviourally relevant information. In several experiments, we presented participants with a variable number of coloured squares (set size 2 or 4; colours sampled from CIE LAB space), which were all equally likely to be probed. One third of all trials was neutral (no rewards). In the rest of the trials, half the items were associated with a potential reward (indicated by a black or white stimulus outline). If a reward-associated item was probed, participants received a reward that was either incidental or contingent on recollection accuracy (results are similar between these conditions). Responses were collected by the method of adjustment (mouse-click on a continuous colour wheel), and were fitted with a mixture model. Our results indicate that if reward-associated and non-rewarded stimuli are remembered, recall precision is equal for both. However, reward-associated stimuli have a higher chance of being recollected. In addition, recall precision for a set of two neutral stimuli was better than recall precision for two reward-associated stimuli in a set of four. Thus participants' recollection of potentially rewarded information was affected by the presence of non-rewarded information. At the very least, non-rewarded items acted as distractors during VWM encoding. An alternative possibility is that all items are initially encoded, but non-rewarded items are subsequently discarded during maintenance. This would result in the observed equal recall precision for reward-associated and non-rewarded items, as well as a higher guessing rate for non-rewarded items.

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43.4062 **Gestalt Grouping Cues Can Improve Filtering Performance in Visual Working Memory** Ayala Allon[1](ayalaallon@gmail.com), Roy Luria[1, 2]; [1]School of Psychological Sciences, Tel-Aviv University, Israel, [2]Sagol School of Neuroscience, Tel-Aviv University, Israel

We investigated compensation mechanisms aimed at preventing task-irrelevant items from entering the limited Visual Working Memory (VWM) workspace. Previous studies have shown that Gestalt grouping cues improve VWM performance. Yet, it is unknown whether Gestalt grouping cues can be used to ameliorate filtering performance in VWM. In Experiment 1 participants preformed a change-detection task in which they viewed memory arrays with either three targets, six targets, or three targets and three distractors (i.e., the filtering condition), and where asked to remember only the targets' colors and to ignore the distractors (based on their shape). In the filtering condition, the targets formed a Kanitza triangle (closure), appeared in a triangle-like configuration (proximity), or appeared at random positions. We found that the proximity condition was able to ameliorate filtering performance. However, the closure condition did not further improved filtering performance (beyond proximity) when the targets formed a Kanitza triangle. Presumably, grouping the targets biased their selection over the distractors, resulting in a better performance. Previous studies have shown that different processes underlie selection of targets and rejection of distractors. In Experiment 2, participants preformed the same task as in Experiment 1, however, this time we implemented the Gestalt grouping cues on the distractors. Similar to Experiment 1, filtering performance was better in the proximity condition and the closure condition did not further improve filtering performance when the distractors formed a Kanitza triangle. The results of this experiment demonstrate that grouping the distractors served to ignore them, either by directly inhibiting distractors selection or by indirectly reinforcing targets' encoding. We conclude that grouping affects filtering performance via targets selection or distractors de-selection processes.

43.4063 **Motion cues facilitate feature updating in mental rotation** Dian Yu[1](dianyu2017@u.northwestern.edu), John Plass[1], Satoru Suzuki[1], Steven Franconeri[1]; [1]Department of Psychology, Northwestern University

The ability to mentally rotate complex images such as models of mechanical, chemical or biological structures is crucial for success in science and engineering. Our recent work suggests that the capacity of mental rotation is severely limited for updating local features such as colors and shapes of parts (Xu & Franconeri, 2015). We hypothesized that local-feature updating may be facilitated by providing appropriate motion cues during mental rotation. Observers were shown a plus-shape (400ms) with four distinctly colored arms, and asked to imagine the shape rotate clockwise by 90° during a short interval (120ms). During this interval, the screen was either blank, or it unpredictably depicted various rotation animations of the black outline of the plus-shape. Observers learned about the animations before the experiment and were instructed that the animations would be irrelevant. The plus-shape reappeared following the mental-rotation interval and observers determined whether it reflected their rotated mental image or two colors had been swapped (50% of trials). Trials where no color-swap occurred allowed the most straightforward test of whether the depicted image matched the observers' mental image of a 90° clockwise rotation, while the color-swapped trials provided a check for response bias. Relative to the blank-interval condition, the identification of the correctly rotated images was improved by a clockwise-rotating animation, hurt by a counterclockwise-rotating animation, and unaffected by other control animations. The rejection of the color-swapped images was unaffected by any of the animations, ruling out response bias as an explanation. Because observers were clearly instructed that animations may be misleading (and they reported trying to ignore the animations), the motion of the irrelevant animation appears to influence feature location updating in an automatic fashion. The presence of motion information may spontaneously 'drag' features to their new locations during mental rotation.

43.4064 **Expecting the unexpected: expecting to be surprised reduces attribute amnesia** Hui Chen[1](psychenhui@gmail.com), Brad Wyble[2], Baruch Eitam[3]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University, [2]Department of Psychology, Pennsylvania State University, [3]Department of Psychology, University of Haifa

Recently we reported a counterintuitive phenomenon, termed attribute amnesia, in which participants failed to report a just-attended attribute (e.g., color or identity of a letter) in a surprise test (Chen & Wyble, 2015, 2016, Chen, Swan, & Wyble, 2016; Eitam, Yeshurun, & Hassan, 2013). Despite being unable to report the attended attribute on the surprise trial, participants could correctly report the same attribute on the first control trial (directly after the surprise trial) wherein their expectation had changed so that they now expected to have to report that attribute. These findings suggest that expectation plays a critical role in determining the reportability of attended information. Here we ask whether an expectation change would improve memory performance for only the attribute that had been unexpectedly probed by the surprise question (i.e. specific improvement hypothesis), or alternatively, would the change improve reportability of all attributes of that target object (i.e. general improvement hypothesis). To distinguish between these two possibilities we used a double-surprise test paradigm, wherein participants were probed on two different attributes of a target in two separate surprise questions. The results showed that once participants were unexpectedly probed about an attribute, their memory performance on the 2nd surprise question was improved on other attributes of the target. This was true even when 15 trials elapsed between the 1st surprise test and the 2nd. These results support the general improvement hypothesis and show that when expectations about information (ir) relevance are violated within a task, participants "broaden" their set to include multiple attributes of the object, rather than just the queried attribute. This change in strategy endured for at least several minutes.

43.4065 **Target recognition is impaired by spatial attention deployed to its location during the retention interval** Sori Kim[1](sorikim0602@gmail.com), Min-suk Kang[1,2]; [1]Psychology, Sungkyunkwan University, [2]Center for Neuroscience Imaging Research, IBS

The shift of spatial attention within visual working memory improves the memory performance of those attended items if spatial information is task-relevant. In this study, we investigated whether this attentional effect holds when the spatial information is task-irrelevant. We prepared the two versions of visual working memory tasks based on the relevance of spatial information, and presented a secondary task to shift spatial attention during the retention interval. In the change-detection task, in which spatial information was task-relevant, one group of participants made a judgment whether the probe item presented at one location was the same with or different from the memory item presented at the corresponding location. In the recognition task, in which spatial information was task-irrelevant, the other group of participants made a presence or absence judgment for a single item presented at the center of the screen regardless of their positions. To shift spatial attention during the retention interval, the participants were presented with a circular patch and discriminated its color (red or blue). The patch was presented at one of the three locations. In the congruent condition, the patch was presented at the target location. In the incongruent condition, the patch was presented at one of the non-target locations. In the neutral condition, the patch was presented at the center of the screen. We found that recognition of the target was impaired to a greater extent in the congruent condition than the neutral condition while we did not find similar pattern in the change-detection task. These results suggest that the effect of attentional shift is reduced if the spatial information is task-irrelevant.

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43.4066 **Reconsidering the focus of attention: Cued items contain more information but are not more accessible** Myriam Sbeiti[1](ms8326@nyu.edu), Daryl Fougnie[2], Timothy Brady[3]; [1]New York University, [2]New York University Abu Dhabi, [3]University of California San Diego

The focus of attention (FOA) is a special state within working memory in which items are assumed to be directly accessible. Here, we gave participants two chances to report the color of a stimulus stored in working memory. The second report is meaningful only if information is not fully retrieved during the first response. If the FOA is really a state of better access, the second report should be beneficial for items outside the FOA, but not beneficial for items inside the FOA. In two experiments on color working memory, we used retro-cues, presented after encoding, but prior to test, to put items in the FOA (Expt. 1, set size 5, n=17; Expt. 2, set size 4, n=15). 75% of trials were cued (100% valid). In each trial, participants were given two chances to indicate the color of the tested item. In the first response, participants chose any color on a color wheel. In the second response, participants chose between the correct color and an incorrect foil color, both equidistant from the first response in color space. Thus, if the first response reflected what people knew about the item, performance should be at chance (50%) for that response. Cued trials had lower guess rates and precision estimates than uncued trials (first response). Importantly, performance on second report was well above chance for both trial types (Expt. 1 cued 69.4%, uncued 61.6%; Expt. 2 cued 69.3%, uncued 65.8%), indicating a failure to retrieve stored information during the first response, even for items in the FOA. This finding is inconsistent with the assumption that the FOA is a state of improved access. Instead, we suggest that items in the FOA have more information, but that being in the FOA does not change the nature of retrieval processes.

43.4067 **Expertise prompts initial faster processing followed by increased short-term memory** Jonas Dall[1,2](jdall@hum.aau.dk), Katsumi Watanabe[3,4], Thomas Sørensen[1,2]; [1]Institut for Communication and Psychology, Aalborg University, [2]Sino-Danish Center for Education and Research, [3]Faculty of Science and Engineering, Waseda University, [4]Research Center for Advanced Science and Technology, The University of Tokyo

Attention is a process of prioritising cognitive recourses to task-relevant stimulus. A number of studies have demonstrated various processing limitations in attention; for example, visual short-term memory (VSTM) only retains a limited number of objects (Sperling, 1960). An increasing number of studies exploit formal models like Theory of Visual Attention (Bundesen, 1990) to investigate the modulation of attentional parameters in more specific detail (e.g. in synaesthesia; see Ásgeirsson, Nordfang & Sørensen, 2015). Previous studies (e.g. Chen, Eng & Jiang, 2006) have argued that capacity limitations are surprisingly robust and resilient to training and expertise. This notion has been challenged by recent studies on the noticeable influence of expertise on VSTM (Sørensen & Kyllingsbæk, 2012; Dall et all, 2016). The current study extends the results reported by Dall et al. (2016) on the influence of expertise on VSTM, into attention by analysing the processing speed and the threshold of visual attention as well as VSTM. The experiment was comprised by three conditions: two control conditions (line drawings and Latin letters) and a critical condition (Japanese hiragana). Three groups with varying degrees of expertise in Japanese reading participated: Danish students (novice), Danish students studying Japanese (trained), and Japanese students (expert). The results showed that while expertise enhanced VSTM only for the expert group, replicating our previous study (Dall et al., 2016), it did not affect the threshold for visual attention. Furthermore, the processing speed was significantly slower for the novice group, leaving the other two (trained and expert) groups about the same. The present results suggest that, while the processing speed is affected by expertise, the effects reach an asymptote long before changes in VSTM.

43.4068 **Relational memory is enhanced in the attentional boost effect** Hamid Turker[1](hbt7@cornell.edu), Khena Swallow[1]; [1]Department of Psychology & Cognitive Science Program, Cornell University

In the Attentional Boost Effect (ABE), increasing attention to a target in a detection task facilitates performance in a concurrent encoding task. For example, people better remember visual scenes that were encoded at the same time that a superimposed square appeared in a color that required a response (i.e., a target). Thus, attending to targets facilitates memory for the background scene. In two experiments, we asked whether target detection also facilitates relational memory for the background scene, an associated object, and task-irrelevant features of that object. In Experiment 1, participants encoded a series of scenes (1000 ms duration; 0 ms ITI) and pressed a button whenever the superimposed object was a target shape (e.g., a circle; 200 ms duration). Objects appeared in one of two colors, which were task-irrelevant. Participants were subsequently tested on their memory for the scene, the object that appeared with that scene, and the color of the object. Replicating the ABE, scenes paired with targets were better recog-

Monday AM

nized than scenes paired with distractors. Participants also better remembered the task-relevant shape of the object that appeared with target-paired scenes. However, there was no difference in memory for color. Thus, target-detection enhances relational memory for scenes and relevant, but not irrelevant, features of concurrently presented objects. In Experiment 2, we asked if participants remembered only that a scene had been presented with a target rather than a distractor. If so, participants would be unable to indicate which of two equally familiar targets appeared with that scene. However, when targets and distractors were faces of each gender, participants nevertheless better identified which of two target-faces appeared with a target-paired scene than distractor-faces with distractor-paired scenes. These data suggest that target detection facilitates memory for concurrent stimuli in an event, implicating a role for regions involved in encoding and retrieving episodic memories.

43.4069 **The costs and benefits of top-down control over visual long-term memory encoding** Christopher Sundby[1,2](christopher.s.sundby@vanderbilt.edu), Geoffrey Woodman[1], Keisuke Fukuda[3]; [1]Department of Psychology, Vanderbilt University, [2]School of Law, Vanderbilt University, [3]Department of Psychology, University of Toronto Mississauga

Visual long-term memory allows us to store a virtually infinite amount of visual information (Standing, 1973; Brady et al., 2008). However, our ability to encode new visual information fluctuates from moment to moment. Here, we investigated the extent to which we have voluntary control over these periodic fluctuations in the quality of visual memory encoding. More specifically, we sequentially presented pictures of real objects and instructed participants to try to remember all of them. We pre- and post-cued a fraction of the stimuli for participants to "try harder to remember" (up-regulation) and to "try not to remember"(down-regulation). We found that visual memory encoding can only be up-regulated, and that both pre- and post-cues are equally effective. Next, we examined the negative side effects of voluntary up-regulation of visual memory encoding by manipulating the cue probability. Here we found that, although the cueing benefit was constant for both low (20%) and high (50%) cueing probabilities, the cueing benefit for the high cueing probability condition was primarily driven by the impaired visual memory encoding of uncued stimuli. A follow-up experiment demonstrated that this negative side effect of voluntary up-regulation of visual memory encoding is manifested as both retrograde and anterograde encoding impairment of temporally adjacent visual memories. Taken together, our findings demonstrate that top-down control of visual long-term memory storage can prioritize certain memories, but this prioritization has a dark side in that it casts a shadow over temporally adjacent objects. This research was supported by the National Institutes of Health (R01-EY019882, R01-EY025275, R01-MH110378, P30-EY08126, and T32-EY007135).

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EYE MOVEMENTS: REMAPPING AND APPLICATIONS

Monday, May 22, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4070 **Evidence that perisaccadic compression is related to uncertainty about the target's position** Maria Matziridi[1](Maria.Matziridi@psychol.uni-giessen.de), Eli Brenner[1], Jeroen Smeets[1]; [1]Department of Human Movement Sciences, Research Institute MOVE, Vrije Universiteit Amsterdam, the Netherlands

During the last decades, many studies have examined the pattern of errors that people make when localizing stimuli that are presented briefly (flashed) near the time of saccadic eye movements. One systematic feature of the errors is a systematic mislocalization towards the endpoint of the saccade. This phenomenon is called perisaccadic compression and its cause is not clear yet. We have proposed that perisaccadic compression arises from a combination of temporal uncertainty about the time of the flash and a bias to believe that what one has seen was where one was looking (Maij et al., 2011, Matziridi et al., 2014; 2015). If this is really the cause, we expect perisaccadic compression to be correlated with any other measure of uncertainty that we can measure. We expect participants who are uncertain about the location of a flash to take more time to indicate its perceived location. We therefore reanalysed the data of several previous studies to examine whether the amount of compression is correlated with the time it takes participants to indicate the perceived location of the flash. We found, indeed, that participants who took longer to respond (indicating a high uncertainty) had higher levels of compression than ones who took less time to respond (indicating a low uncertainty). This finding supports the idea that uncertainty plays a crucial role in the errors that are made when localizing perisaccadically flashed stimuli.

43.4071 **Is the efference copy of a saccade influenced by a perceptual illusion?** Delphine Massendari[1](delphine.massendari@gmail.com), Matteo Lisi[1], Patrick Cavanagh[1,2], Thérèse Collins[1]; [1]Laboratoire psychologie de la perception, CNRS UMR 824, Université Paris-Descartes, [2]Psychological and Brain Sciences, Dartmouth College, Hanover, NH

The double-drift stimulus leads to a large discrepancy between the physical path of a moving Gabor and its perceived direction. Surprisingly, saccades to the double-drift stimulus do not show any effect of the illusion (Lisi & Cavanagh, 2015). Here, we asked whether the efference copy of the saccade was influenced by the illusion. This question was addressed by using saccadic suppression of displacement. We presented a single Gabor moving along a linear trajectory with internal motion (double-drift condition) or without (control condition). In the double-drift condition, the perceived orientation of the path could deviate by 45° or more from its physical path while in the control condition the physical and the perceived paths were the same. During stimulus presentation, participants keep their eyes focused on a fixation dot while the drifting Gabor appeared and moved in the periphery. After 1800 ms of stimulus presentation, the fixation dot was removed, serving as the go-signal to make a saccade toward the moving Gabor. As soon as a saccade was detected, a blank of 250 ms occurred after which the Gabor reappeared and remained stationary at a new location to the left or the right of its original location. Participants were asked to report the direction of the jump. We hypothesized that if the expected post-saccadic target location is influenced by the illusion, we should observe a shift in the psychometric function of displacement judgment for the double-drift, compared to the control condition. Indeed, the psychometric function of the double-drift condition was shifted by about 0.5° compared to that of the control condition. Thus, displacement judgments were affected by the illusion, suggesting that the perceived location plays a role in the predicted location of the target after a saccade even though it has little effect on the saccade itself.

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43.4072 **Dynamically tracking the neural signatures of visual attention across a saccade** Jiageng Chen[1](chen.5805@osu.edu), Xiaoli Zhang[1], Julie Golomb[1]; [1]Department of Psychology, The Ohio State University

To maintain visual stability, the retinotopic coordinates of objects need to be remapped across each saccade. Recent evidence suggests that visual attention is also remapped, occurring in two stages: a fast remapping to the new retinotopic location followed by a slower disengagement from the prior representation (i.e., retinotopic trace; Golomb, L'Heureux, & Kanwisher, 2014). However, it remains unclear how the focus of attention is dynamically shifted over the entire perisaccadic period. In the current study, we recorded steady-state visual evoked potentials (SSVEP) in human EEG to dynamically read out which objects subjects were attending to across each saccade. Three orientation gratings were displayed on the screen with two possible fixation locations between them ("O+O+O" pattern). Subjects maintained attention on the central patch and reported an occasional orientation shift. In half of the trials, subjects also made a saccade from one fixation point to the other as soon as a saccade cue appeared. Thus, the central patch was the spatiotopic (attended) location, while the other two patches represented the "predictive-remapping location" and "retinotopic-trace location" respectively. All three patches flickered at different frequencies, such that each location was tagged with a unique SSVEP spectral peak. Time-frequency analysis was performed on EEG data to calculate the inter-trial coherence (ITC) corresponding to each location over time. ITC was greatest at the spatiotopic (attended) location during baseline periods (outside the perisaccadic window), indicating that subjects were successfully attending to the spatiotopic location. Immediately after each saccade, the

ITC difference between the spatiotopic location and retinotopic-trace location was reduced, consistent with a temporary lingering of attention at the retinotopic-trace location subsequent to each saccade. Preliminary data also found weaker evidence for predictive remapping. The current experiment provides a new method to dynamically track the neural signatures of visual attention across a saccade.

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43.4073 Perceptual continuity across saccades: evidence for rapid spatiotopic updating

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The retinotopic organization of visual information is shifted with each saccade. Yet, we experience a continuous stream of visual information. The discrepancy between the disrupted retinotopic organization and apparent perceptual continuity of visual information has been studied for centuries. There is still an ongoing debate whether perceptual continuity across saccades is illusory, or whether retinotopic representations of visual information are updated across saccades. Recent studies provided a considerable amount of evidence in favour of spatiotopic updating, enabling perceptual continuity. Importantly, these studies showed that the build-up of spatiotopic coding takes up to 500 ms, plus saccade latency. Here, we challenge this view by showing that spatiotopic updating can take place within the saccadic latency interval (±200 ms). In our experiments, we used a motion illusion (High Phi) where the random texture of a slowly rotating annulus is replaced with four different random textures. Even though the textures are not correlated, the slow rotation can induce a strong percept of a large backward jump when the textures are replaced. We have previously shown that the illusory backward jump in the High Phi illusion can be induced spatiotopically, using long presaccadic inducer intervals (Fabius et al., 2016, Sci.Rep.). Here, we show that this updating can be detected even when using presaccadic inducer intervals as short as saccade latencies to visual onsets. These results provide evidence for rapid spatiotopic updating of visual information across saccades in much shorter regime than previously assumed.

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43.4074 Parallel shifts: evidence for simultaneous predictive remapping across multiple attentional targets

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Just before a saccadic eye movement we experience changes in perception brought about by shifting neuronal receptive fields in oculomotor areas of the brain. These receptive field shifts and the associated perceptual phenomena are called presaccadic remapping. There remain open questions regarding 1) whether presaccadic remapping involves prediction of the post-saccadic location of visual targets and 2) whether presaccadic mapping occurs in parallel for locations across the visual field or only for a single attended location. In a series of previous studies, we used reverse correlation with a trans-saccadic luminance discrimination task to construct "perceptive fields" that revealed the spatiotemporal pattern of information integration in perceptual remapping. Observers monitored a rapidly changing luminance stream (target) flanked on either side by similarly constructed distractors while making a saccade and classified the target as light or dark. We found that perceptual remapping operates in manner consistent with predictive remapping, integrating information from the prospective (post-saccadic) retinal location of an attended target. Moreover, we showed that this remapping is attention-based and spatially precise. In the current study, we extended the reverse-correlation analysis to determine whether presaccadic remapping occurs in parallel across multiple locations. In the revised task, observers simultaneously attended two flickering targets across a single saccade and were asked to make independent luminance judgments about each of the two targets. The reverse correlation analyses revealed predictive presaccadic remapping at both target locations, each consistent with the pattern observed in the previous single-target studies. These results suggest that a saccade can trigger predictive attentional remapping independently and in parallel across multiple locations in the visual field.

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43.4075 Auditory spatial attention across eye-movements is remapped in retinotopic coordinates

Stefan Van der Stigchel[1](s.vanderstigchel@uu.nl), Nathan Van der Stoep[1], Martijn Schut[1]; [1]Experimental Psychology, Utrecht University, Utrecht, the Netherlands

Our senses generally complement each other: whereas vision gives us an uncontested spatial resolution, audition allows for localization in 360 degrees. To promote unity between sensory systems, sensory signals must be integrated into a multimodal coordinate system. Visual information is retinotopically encoded, and head-related auditory information is transformed into retinotopic coordinates in the superior colliculus. Because the eyes frequently move, the updating of spatial information with regards to the retina is crucial for the ability to localize sensory information after a saccade. This updating is known as remapping of spatial attention, the after-effects of which are reflected in facilitated post-saccadic reaction times to visual stimuli presented at the location of a retinotopic trace. However, whether auditory spatial attention is remapped in a similar manner is currently unclear. In the current study we investigated whether auditory spatial attention is remapped across eye movements. We designed a task in which participants allocated their attention to a peripheral location, followed by a saccade. After the saccade was completed, an auditory/visual target could either be presented at the location of the retinotopic trace or a novel location. Participants were tasked with reacting to this target as quickly as possible. We observe that auditory and visual targets presented at the location of the retinotopic trace were reacted to significantly faster immediately after the saccade than at the non-retinotopic locations. The facilitation of reaction times to post-saccadic targets at the location of the retinotopic trace diminished as the delay between saccade offset and target onset increased. Our study is the first to show that the effects of remapping spatial attention across saccades happens in retinotopic coordinates regardless of the sensory modality (i.e., audition or vision). Taken together, these results suggest that sensory unity is maintained across saccades by encoding audiovisual information into a retinotopic reference frame.

43.4076 Adaptation to distortions of natural scenes is retained across saccades

Selam Habtegiorgis[1](selam-wondimu.habtegiorgis@uni-tuebingen.de), Katharina Rifai[1], Siegfried Wahl[1]; [1]Institute for Ophthalmic Research, Eberhard Karls University, Tübingen, Germany

Vision aid optical elements, such as progressive additional power lenses, spatially distort the image of the natural environment disparately across the different parts of the visual field. Eye movements thereby continuously shift the distortions in the retinal plane. While people adapt to such spectacles, the visual system seems to compensate for distortions regardless of their continuous retinal displacements during eye movements. Neural mechanisms involved in distortion adaptation might transfer their plasticity across saccades. Here we used reference frames of adaptation aftereffects to assess if distortion is processed anew at every fixation or if it is retained across saccades to achieve perceptual stability. In a psychophysical experiment, observers viewed geometrically skewed natural image content for 8 minute to induce adaptation. A saccade was subsequently executed to a new fixation point and skew adaptation was measured at retinotopic and spatiotopic locations as well as at a location which was neither retinotopic nor spatiotopic. Adaptation aftereffects were tested in an adjustment procedure. The adaptation aftereffect, i.e. the point of subjective equality (PSE), was defined by the skew amplitude of the test stimuli which was perceived to be undistorted by the observers. The skew adaptation information was partially transferred to the new fixation. Retinotopic and spatiotopic locations showed significant skew adaptation aftereffect wherein the PSE shifted in the direction of the adapting skew direction. In contrast, no aftereffect was observed at the location which was neither retinotopic nor spatiotopic. Therefore, the visual system preserves retinotopic and spatiotopic distortion information across saccades. The spatiotopic distortion information is conceivably used to counterbalance the saccade induced retinal shifts of the distortions, thereby mediating retinotopic and spatiotopic representations of the distortions.

43.4077 **Peri-saccadic perceptual mislocalization is different for upward saccades** Ziad Hafed[1](ziad.m.hafed@cin.uni-tuebingen.de), Nikola Grujic[2], Nils Brehm[2], Cordula Gloge[2], Weijie Zhuo[2]; [1]Centre for Integrative Neuroscience, Tuebingen, [2]Graduate Training Centre of Neuroscience, Tuebingen

Brief visual flashes around the time of saccades can be perceptually "compressed" towards the saccade target. Consistent with this, Kaiser and Lappe (2004) tested flash positions orthogonal to the saccade vector for rightward or downward saccades, and they found orthogonal perceptual shifts. However, the shifts were asymmetric, with flashes nearer to initial fixation than the saccade target showing weak or no orthogonal mislocalization component. Models accounting for such asymmetry suggest that it arises because of oculomotor-based gain modulation of visual maps having "foveal magnification". However, different neural maps (whether oculomotor versus visual; or whether visual maps in different brain areas) might have different patterns of neural tissue "magnification". Motivated by our recent findings of upper visual field magnification in the superior colliculus (Hafed and Chen, 2016), we compared peri-saccadic mislocalization around the time of upward saccades to that around other movement directions. Four naïve subjects made 14.6 deg saccades (to the right, left, up, or down). At different times relative to saccade onset, we presented a brief (~12 ms) white square (0.76 deg) at one of 8 equally spaced positions around the saccade target (at a radius of 3.6 deg). Peri-movement compression occurred for all saccade directions, but upward saccades showed qualitatively different patterns. First, for flashes farther away from the saccade target, the component of mislocalization along the saccade vector was stronger for upward saccades than for other directions. Second, for orthogonal flash locations, upward saccades had strong orthogonal mislocalization components even for flashes nearer to initial fixation. For horizontal saccades, we also noticed that flashes above the horizon showed no orthogonal mislocalization at all, but flashes below replicated Kaiser and Lappe (2004). Our results constrain shapes and sources of oculomotor and visual signals invoked in models of peri-saccadic perception, and suggest an important role for the superior colliculus.

43.4078 **Microsaccades while aiming are not just limited by gaze relocation demands.** Rakesh Nanjappa[1](rnanjappa@sunyopt.edu), Robert McPeek[1]; [1]Graduate Center for Vision Research, SUNY College of Optometry

Microsaccades are part of oculomotor strategy during fine acuity visuomotor tasks. For example when threading a needle, microsaccades initially relocate gaze between the distinct objects of interest to facilitate fine motor adjustments, after which their rate declines as the objects move closer. A similar trend in microsaccade rate is seen during shooting tasks even though the objects involved do not move in a predictable manner. We investigated microsaccade characteristics while subjects controlled the direction of a slow moving circle with a gamepad to make it concentric with another fixed circular target and pressed a button to trigger a 'shoot' event. In one condition, both the fixed and moving targets appeared straight ahead at one degree separation between their centers. In the second condition the targets were presented with similar separation and motion at 5 degrees eccentricity, and subjects maintained fixation on a central target and used peripheral vision to perform the task. Aiming performance was much better with the use of central vision and dropped dramatically when peripheral vision was used. Microsaccade direction was highly correlated with the moving target's position in both the conditions. There was no significant coupling between the timing of microsaccades and motor adjustments. In the central viewing condition, microsaccade rate dropped just before the shooting event, as observed in earlier studies. This drop has been associated with the narrowing separation between the two objects and the resulting lack of need for microsaccades to foveate them alternately. Surprisingly, we found a similar drop in microsaccade rate just before shooting in the peripheral viewing condition in which microsaccades do not relocate gaze between objects. This indicates that the drop in microsaccade rate is affected not only by changes in gaze relocation demands, but also by other factors, such as attention or the perceptual decision-making process.

43.4079 **Fixation and pursuit show similar behavior with complex stimuli** Scott Watamaniuk[1,2](scott.watamaniuk@wright.edu), Stephen Heinen[2]; [1]Department of Psychology, Wright State University, [2]The Smith-Kettlewell Eye Research Institute

During smooth pursuit, retinal image motion helps stabilize a target by modulating eye velocity. We previously showed that increasing the number of elements comprising a pursuit target increases open-loop eye acceleration (Heinen et al., 2016). We hypothesized that pursuit was facilitated because more stimulus elements created a stronger motion signal. The purpose of fixation appears similar to that of pursuit – to stabilize a visual target. If true, the fixation system might also utilize a motion signal to stabilize gaze since during fixation, the eyes continuously create retinal motion as they drift across a target. To test this, we asked if eye velocity during fixation is altered when the number of stimulus elements in a fixation target is changed. Observers fixated either a small spot target, a 6° circular array of 8 dots, or a 9-dot conglomerate of these stimuli. Eye movements were measured using an EyeLink 1000 eye tracker. We found that smooth eye velocity during fixation decreased when the number of elements in the stimulus increased, evidence that retinal motion facilitated fixation as it does open-loop pursuit acceleration. During pursuit, catch-up saccades are not linearly related to the number of stimulus elements, rather they occur more frequently when a stimulus has a central element (Heinen et al., 2016). To see if the fixation/pursuit analogy extends to saccadic intrusions, we also looked at microsaccades rate for the different stimulus configurations. Like catch-up saccades during pursuit, during fixation microsaccades were also more prevalent when there was a central element. The results suggest that the fixation system uses a motion signal to reduce slow drifts and increase image stability, and might do so using retinal-motion feedback. Moreover, small central elements encourage foveation during fixation as they do during pursuit.

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43.4080 **Eye movement patterns when driving in real environment** Hong Xu[1](xuhong@ntu.edu.sg), Bo Du[1], Jian Sheng Yeung[2,3], Yiik Diew Wong[2]; [1]Division of Psychology, School of Humanities and Social Sciences, Nanyang Technological University, Singapore, [2]Center for Infrastructure Systems, School of Civil and Environmental Engineering, Nanyang Technological University, Singapore, [3]Land Transport Authority, Singapore

Previous studies have investigated drivers' visual features when drivers entering and exiting tunnels. However, few studies have attempted to investigate drivers' visual attention in different real environment (e.g., open roads and underground tunnels). This study examined drivers' eye movement patterns when they were driving on open road and tunnel expressways in Singapore. Twenty-two drivers were recruited for the study, and the total driving distance was 25 km including 9 km tunnel section. Drivers' eye movement was recorded simultaneously using a head-mounted mobile eye tracker (Mobile Eye XG, ASL). We found that drivers experienced more fixations and blinks when driving on open roads than in tunnels during the same period of effective times (Wilcoxon Signed rank test, as the data doesn't follow normal distribution; same analysis in the following); and instantaneous velocity for saccades was significantly higher when driving on open roads. However, longer fixation durations were observed for drivers in tunnels. The findings suggest that attention distribution is more concentrated when driving in tunnels than open roads, and may reflect heavier cognitive load in tunnels. Interestingly, drivers experienced more stable fixation in horizontal direction (e.g., peak velocity) and less stable fixation in vertical direction in tunnels (e.g., dispersion). Furthermore, drivers in tunnels gazed more at the center of the visual field (e.g., car ahead and road ahead); whereas the gaze pattern for open road driving spread toward other items in the scene (e.g., mirror, road side, and far ahead/sky). The heterogeneous surroundings for open roads may attract more diverse attention than tunnels. Findings from the study may help shed light on the mechanisms of attention when navigating in real environment and provide insights for road design and regulation for safety in high speed self motion.

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43.4081 **Visual Attention and Learning from Multimedia With and Without an Anticipation Guide** Natercia Valle[1](nvalle@ufl.edu), Jiahui Wang[1], Pasha Antonenko[1], Wenjing Luo[1], Ryan Rushing[1]; [1]School of Teaching and Learning, College of Education, University of Florida

Anticipation guides are used in reading instruction to activate learners' prior knowledge and stimulate interest regarding the topic covered in the text. This strategy has been found effective in improving reading comprehension in content areas like history, physics etc. (Yell et al., 2004). This study tested the efficacy of an anticipation guide within a multimedia learning environment for early childhood education providers. Seventeen early childhood education practitioners and students were asked to use earlylearningflorida.com to learn about "Setting up the Learning Environment". Half of the participants were provided with an anticipation guide (5 accurate and 5 flawed statements that they were to agree or disagree with). Visual attention and navigation patterns were captured using an EyeLink 1000 eye tracker and Screen Recorder software. Learners in the anticipation guide condition performed a significantly larger number of transitions from picture to text ($F(1, 12) = 24.723$, $p < .001$, $\eta 2 = .673$), from text to picture ($F(1, 12) = 27.865$, $p < .001$, $\eta 2 = .699$), and total integrative transitions between text and picture ($F(1, 12) = 27.770$, $p < .001$, $\eta 2 = .698$). Also, they fixated longer on the text after a gaze shift from the picture ($F(1, 12) = 5.591$, $p < .05$, $\eta 2 = .318$), possibly using the picture as an "anchor point" to process textual information at a deeper level. Anticipation guide participants also spent more time processing readings, ($F(1, 12) = 5.433$, $p < .05$, $\eta 2 = .312$), however no significant differences were identified relative to cued recall and knowledge transfer. This study provides tentative evidence that anticipation guides enhance cognitive engagement with multimedia content encouraging learners to spend more time reading and integrating pictorial and verbal information. Follow-up studies using larger samples and in other contexts are needed to further explore the effects of anticipation guides.

43.4082 **Effect of aging on ocular fixation and microsaccades during optic flow** Angelo Arleo[1](angelo.arleo@inserm.fr), Marcia Bécu[1], Guillaume Tatur[1], Alix de Dieuleveult[1], Changmin Wu[1], Silvia Marchesotti[1], Denis Sheynikhovich[1]; [1]Sorbonne Universités, UPMC Univ Paris 06, INSERM, CNRS, Institut de la Vision, Paris, France

Visual fixations correspond to moments of "useful vision", unlike saccades during which we are blind. Optic flow can influence the statistics of fixational eye movements, and therefore affect the quality of visual information accessible to the brain. While aging is known to alter the processing of dynamic visual cues, the influence of optic flow on fixational eye movements remains poorly characterized, partly due to the difficulty of microsaccade analysis in aged subjects, caused by the presence of pupil detection noise. This study assessed ocular fixation statistics and microsaccade characteristics under no-flow (control) as well as radial and tangential optic flow conditions in 51 subjects (21 – 80 y/o). All subjects were ascertained to be healthy by visual, vestibular, sensorimotor, and cognitive clinical examination. Eye movements were recorded at 1000 Hz in head-fixed conditions. Microsaccades were analyzed using a novel unsupervised clustering method that permits reliable detection in the presence of high-frequency pupil detection noise. The algorithm's performance was compared against state-of-the-art methods on both noiseless and noisy data using a ROC analysis. We found that the fixation area was larger in aged compared to young subjects. All optic flow conditions reduced the fixation area to a similar extent in all age groups. Moreover, tangential optic flow significantly affected the ocular fixation drift slope, and it amplified the extent of drift significantly more in aged compared to young subjects. Our microsaccade analysis extends previous data, showing that healthy aging significantly increased microsaccade frequency, amplitude, and peak velocity. Moreover, optic flow influenced all microsaccade characteristics, by reducing frequency, amplitude, and peak velocity. Tangential optic flow significantly triggered microsaccades in the opposite direction to the flow. Importantly, this directional bias tended to be stronger in old adults compared to young subjects.

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43.4083 **Instructor Presence, Visual Attention, and Learning in Educational Video: Content Difficulty Matters** Jiahui Wang[1](jwang01@ufl.edu), Pavlo Antonenko [1], Ethan Fieldman[2,3]; [1]School of Teaching and Learning, College of Education, University of Florida, [2]Lastinger Center for Learning, University of Florida, [3]Study Edge Corporation

In an effort to reach more students, educators are designing online learning experiences, particularly in the form of online videos. While many instructional videos feature a picture-in-picture view of instructor, it is not clear how instructor presence influences learners' visual attention and what it contributes to learning and affect. On one hand, instructor presence could elicit beneficial socio-emotional responses and provide additional nonverbal modalities of interaction. On the other hand, it introduces complex visual stimuli that may distract learners and hinder cognition, especially when the content itself has already imposed a high intrinsic cognitive load. This study explored the impact of instructor presence on visual attention, learning and affect in mathematics instructional videos of varying content difficulty. Thirty-six participants (age 18-21, 21 female) each viewed two 10-minute-long mathematics videos (easy and difficult topics), either with instructor present or absent. When instructor was present, the main frame was devoted to a Khan Academy style pencast, and the bottom right-hand corner displayed a shoulder-up video of the instructor. Findings suggest considerable dwell times when the instructor was present in either easy topic (25%) and or difficult topic (22%) video, even though the instructor only occupied approximately 7% of the entire screen. Also, the effect of content difficulty on the instructor fixation count percentage was significant, $F(1, 34) = .042$, $p < .05$, $\eta 2 = .130$, with more fixations devoted to the instructor in easy topic video. Although no significant difference in learning transfer was found for either topic, participants' ability to recall information from the easy topic video was better when instructor was present, $F(1, 34) = 8.588$, $p < .05$, $\eta 2 = .202$. Finally, instructor presence had a positive effect on participants' perceived learning and satisfaction for both topics and led to a lower level of self-reported mental effort for difficult topic.

43.4084 **Online eye tracking with consumer-grade webcams: potential and limits** Kilian Semmelmann[1](visionsciences@ksemmelm.de), Sarah Weigelt[1]; [1]Developmental Neuropsychology, Ruhr-Universität Bochum

Within the last decade, online experimentation was established as a viable supplement to in-lab experimentation. While this endeavor started with online questionnaires, recently performance- and reaction time-based paradigms that are used in the field of vision science were added to the list of reliable instruments for online research. To add another method to this inventory, this study aimed to explore the potential and limits of webcam-based online eye tracking through a JavaScript-based gaze estimation library supported by HTML5. By using consumer-grade webcams to acquire data from home, we assume that the advantages of lower costs, parallel, independent data conduction, and easier access to a broader or more special population can be utilized. We employed three tasks (fixation task, smooth pursuit, and free viewing) in an in-lab and an online setting to establish a first common ground of spatial and temporal accuracy. The fixation task allowed us to identify initial saccades and the spatial offset towards the target. During the smooth pursuit task, the same factors were analyzed, but while having a moving stimulus. The third task concentrated on identifying the sensitivity to semantic interpretation of an image by replicating earlier work about attention distribution to regions of interests of a face. Overall, we found the spatial accuracy to be at around 200 px (4° visual angle) offset, for both static and moving stimuli, and we were able to reproduce the findings that eyes get pre-dominantly fixated when viewing faces. Online data showed no difference in accuracy to in-lab data, but exhibited a higher variance, lower sampling rate, and longer experimental durations. These results suggest that web-technology-based eye tracking is suitable for all three tasks and we are confident that the technique will be improved continuously to be available for online experimentation in the field of vision science and beyond.

EYE MOVEMENTS: SACCADES

Monday, May 22, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4085 **Monocular microsaccades; do they really occur?** Martina Poletti[1](martinap@bu.edu), Yu Fang[1], Michele Rucci[1]; [1]Department of Psychological and Brain Sciences, Boston University

The last 15 years have witnessed a renewed and increasing interest in the visual functions of microsaccades. While considerable progress has been made on the resolution of classical debates, one specific issue that has remained controversial is the frequency of monocular microsaccades.

Contrary to classical studies, several recent reports found a considerable percentage of microsaccades (up to 40%) to be monocular. These large numbers of monocular events are suspicious, particularly given that it is now clear that microsaccades serve a similar and precise gaze-centering function as larger saccades (Poletti et al, 2013). That is, while it is reasonable that precise alignment of stimuli may lead to monocular microsaccades, it is surprising to find them in experiments in which subjects observe stimuli on flat displays. Since all recent studies were based on video-based eye-trackers, systems that tend to sacrifice precision for simplicity of use, it has been hypothesized that the surge in monocular microsaccades could be the consequence of measurement artifacts. To investigate this issue, here we examined two binocular oculomotor datasets collected with two of the most precise eye-tracking methods available: Dual Purkinje Image (DPI) tracking and eye coils. DPI data were collected with the head immobilized while subjects fixated on points presented on a display. Coil data were collected during normal head-free viewing, while subjects looked at LEDs at different distances. In both datasets, we found virtually no trace of monocular microsaccades. When the parameters of the microsaccade detection algorithm were relaxed, a few monocular events were signaled; however, manual validation revealed that these events were false alarms. Our results do not exclude the existence of monocular microsaccades, but show that these are extremely rare events in standard experiments. The monocular microsaccades reported by recent studies are likely the outcome of both recording artifacts and suboptimal microsaccade detection algorithms.

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43.4086 Alteration of the microsaccadic velocity-amplitude main sequence relationship after visual transients: implications for models of saccade control

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Microsaccades occur during gaze fixation in order to correct for miniscule foveal motor errors. The mechanisms governing such fine oculomotor control are still not fully understood. In three behavioral experiments, we explored microsaccade control by analyzing the impacts of transient visual stimuli on these movements' kinematics. In two male rhesus macaques, we presented peripheral (Experiment 1) or foveal (Experiment 2) visual transients during an otherwise stable fixation period, and we measured microsaccade times, directions, amplitudes, and peak velocities. In both experiments, visual transients resulted in well-known reductions in microsaccade frequency ~100 ms later. Our goal was to investigate whether microsaccade kinematics would additionally be altered for the few movements happening exactly around this inhibition period. We found that microsaccade amplitudes were modulated by the visual transients, and in predictable manners by these transients' geometry; movements directed "towards" the visual transients had larger amplitudes than movements directed "opposite" the visual transients, and this happened even when the transients were foveal and thus near the microsaccade endpoints. Interestingly, modulations in the peak velocity of the same movements were not proportional to the observed amplitude modulations, suggesting a violation of the well-known "main sequence" relationship between amplitude and peak velocity. We generalized these results to larger saccades in Experiment 3, now involving free scanning and a full-screen flash. We hypothesize that visual stimulation during movement preparation affects not only a topographically-organized saccadic "Go" system driving eye movements, but also a "Pause" system inhibiting them. If the "Pause" system happens to be already turned off despite the new visual input, movement kinematics can be altered by the instantaneous spatial read-out of additional visually-evoked spikes in the "Go" system coding for the visual input's location. Our results demonstrate precise control over individual microscopic saccades, and provide testable hypotheses for mechanisms of saccade control in general.

43.4087 Memory-guided microsaccades

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Microsaccades are commonly described as "involuntary". However, under a variety of task conditions, microsaccade directions, amplitudes, and frequencies can be systematically modulated. While these results hint at voluntary control, they are primarily derived from likelihood measures rather than "at will" triggering of individual movements. Here we asked whether individual movements in the microsaccade amplitude range can be triggered: (1) "on demand" based on an arbitrary instruction, (2) without special training, (3) without visual guidance, and (4) in a spatially- and temporally-accurate manner. Two macaque monkeys and 7 human subjects performed a memory-guided saccade task. In this task, an eccentric flash was presented briefly (~50 ms). Subjects maintained flash location in memory for ~300-1100 ms, after which the fixation spot disappeared, providing a "go" command to generate a saccade to the remembered location. After an additional grace period, the remembered stimulus re-appeared allowing subjects to visually correct any remaining errors. The monkeys were only trained on the task with saccades >3 deg in amplitude, and humans were only given verbal instructions and minimal training. We then collected data from trials of random target eccentricities (0.1-16 deg) and directions (0-360 deg). All subjects naturally generated memory-guided movements even less than 0.5 deg in amplitude. These movements were highly directionally accurate, and while their amplitudes may have been quantitatively less accurate than visually-guided corrections, dependence of landing error on eccentricity was not qualitatively different between the memory and visually-corrective movements. Importantly, we ran the human subjects on control versions of the task with manual pointing, and the memory accuracy for foveal targets was comparable to that of "memory-guided microsaccades". We conclude that microsaccades can be generated voluntarily, and that any spatial inaccuracies in memory-guided microsaccades are likely not due to an inability of the occulomotor system to voluntarily trigger a tiny saccade.

43.4088 Microsaccades in blindsight monkeys

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Patients with damage to primary visual cortex (V1) demonstrate residual performance on laboratory visual tasks despite denial of conscious seeing (blindsight). Macaque monkeys with a unilateral V1 lesion have been used as an animal model for blindsight. After a period of recovery, these monkeys are able to localize visual stimuli in a forced-choice condition while failing to report awareness of identical stimuli in a yes-no detection task, which resembles human blindsight performance. Some residual attentional effects including saliency-guided eye movements and exogenous attention have also been demonstrated in blindsight monkeys. Here we examined whether microsaccades in blindsight monkeys are influenced by endogenous task instructions during Posner-style cueing. Before and after the unilateral removal of V1, two monkeys performed visually guided saccade tasks with a central informative cue. As a pre-cue, either an arrow or, in separate sessions, a color patch was superimposed for 100 ms on the fixation point. This was followed by a cue-target-onset asynchrony of 150-700 ms and then a saccade target at either the cued (80% of trials) or uncued (20% of trials) hemifield. Before the lesions, microsaccades were strongly affected by the cues, with an initial suppression in microsaccade frequency 50-150 ms after cue onset followed by rhythmic volleys of movements. Microsaccade directions were also modulated. After the lesions, there was a marked reduction in the number of microsaccades towards the affected hemifield during steady fixation (before cue onset). However, despite this bias, cue onset still caused modulations in microsaccades that were generally similar to those before the lesion. Consistent with this, the monkeys were also able to utilize the cues in the affected hemifield to direct their saccades to the cued target. These results help constrain models of microsaccade dynamics after peripheral and central cueing, and they highlight how V1 can contribute to such dynamics.

43.4089 Changes in oscillatory brain activity around the time of saccades: an MEG study of voluntary horizontal saccades in near-darkness condition

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Peri-saccadic brain activity in humans has mainly been studied in the context of a perceptual task, making it difficult to disentangle activity related to the task, the visual transients, and saccade execution. To better characterize activity specific to eye movements, we tested participants in a dark room to limit visual transients and gave them no other task than to execute voluntary saccades between two horizontally-aligned and faint fixation points. Their brain activity was recorded with MEG while their eye movements were measured by the means of an eye-tracker and EOG electrodes. We found dramatic and consistent changes in oscillatory brain activity around the time of saccades. First, we observed an alpha power increase in parietal sensors as early as 500ms before saccade onset. This increase was most pronounced in sensors ipsilateral to the direction of the saccade, in a process possibly related to pre-saccadic changes in attention allocation. Second, there was a strong evoked response at fixation onset, likely due to re-afference of the visual signal. In addition, despite the weak visual input, we observed a long-lasting drop in power in a wide range of frequencies (7-40Hz) from 200ms following saccade execution, centered over parietal sensors but widespread over most posterior sensors. The alpha power drop was less pronounced for parietal sensors ipsilateral to the direction of the saccade. More generally, the pattern of oscillatory changes depended on the brain region, with large changes in oculomotor and visual cortical areas. These data indicate that, even with faint visual input, reliable power changes can be observed before and after saccade execution. These results are also useful in interpreting M/EEG studies that involve saccades.

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43.4090 EEG decoding of saccade direction 1.7 s before the saccade

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The goal of this study was to decode motor “decision” to perform a left or a right saccade from EEG signals prior to the saccade. Participants initially fixated a central point on the screen while two targets were presented, one to the left and one to the right of fixation, both on the horizontal meridian at 7° eccentricity. Participants were asked to choose randomly one or the other target for their upcoming saccade but to withhold the eye movement until a go signal was presented 2 s after the target onset. Linear discriminant analyses on the 64 electrode traces were able to decode the direction of saccades at above chance levels starting from ~1700 millisecond before the onset of the saccade. The decoding accuracy reached 95% and above by 720 ms before the saccade. We then attempted to predict the saccade directions based on the horizontal and vertical eye movement records with the assumption that micro-saccades prior to the saccade might indicate its direction. In this case the direction of saccades could not be predicted from the eye movement traces until ~80 milliseconds before saccade onset. Taken together these results suggest that the intended saccade direction can be decoded well before the execution of the eye movements. Decoding motor plans and their accompanying spatial shifts of attention may support the development of brain-machine interfaces allowing paralyzed patients to control a cursor on a computer screen (or other external devices) through saccade motor plans without the need of overt eye movements.

Acknowledgement: European Research Council

43.4091 Transcranial direct current stimulation of the right frontal eye field to affect saccade execution

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The function of the frontal eye fields was first discovered through electrical stimulation, when David Ferrier showed he could evoke saccadic eye movements in monkeys by applying an electrical current. In humans, electrical stimulation of the brain can be achieved with transcranial direct current stimulation (tDCS). tDCS cannot induce sufficient activity to directly evoke saccades, but it can influence the excitability of neurons. By modulating baseline activity in the frontal eye field, tDCS can potentially probe its role in saccade execution, but also in related functions, like shifting spatial attention. One study has systematically explored the effects of frontal eye field tDCS on eye movements (Kanai et al., 2012, Front. Pscyhiatry). They showed that anodal tDCS of the frontal eye field can decrease the median latency of saccades, specifically when saccades were made to targets in the visual hemifield contralateral to the stimulated hemisphere. In the present study, we aimed to replicate and extend this result with a similar experiment. We applied anodal or cathodal tDCS to the right frontal eye field of 15 participants. Before, during, and after stimulation, subjects made eye movements to an eccentric visual target (in a prosaccade task without a gap or overlap between fixation and target onset). Our initial results show that we are unable to reproduce the effect found by Kanai et al.: neither form of tDCS affected the median latency of contra- or ipsilateral saccades. This result suggests that oculomotor functions of the frontal eye fields may not be robustly amenable to tDCS. We are currently trying to replicate our initial results in a larger sample. In addition, we are exploring whether tDCS might instead affect saccade parameters other than (median) latency.

43.4092 Saccadic gain controlled by a visual discrimination task

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Saccade adaptation is a form of motor learning that maintains saccade accuracy in response to new sensorimotor contingencies. We know that reinforcement learning can induce saccade adaptation in the absence of a visual position error suggesting that conventional saccade adaptation might involve general learning mechanisms rather than only specific motor calibration mechanisms. Previously, an arbitrary reinforcer such as an auditory tone or stabilizing the target on the fovea has been successfully used to control changes in saccade gains. We now ask whether adaptation-like modulations in saccade amplitude may be induced by the ability to perform a visual discrimination task using a new gaze-contingent paradigm. An experimental paradigm was designed in which the post-saccadic retinal error was canceled by extinguishing the target as soon as the saccade onset was detected following the target step from the fixation location (45-degree upward and leftward with random amplitude). The visual background was entirely covered by ‘8‘ symbols of 7 by 7 pixels. At saccade offset, all background symbols transiently (60 ms) changed and participants were instructed to report which symbol was displayed (either 2,3,5 or E) in a 4AFC task. However the possibility to perform the discrimination task depended on the saccade horizontal gain: if a gain criterion (based on a moving median computed over the 50 previous trials) was not met one of four irrelevant symbols was displayed such that no correct response was possible. In two participants the criterion encouraged an increase in horizontal gain. The percentage of gain change computed with respect to the mean of the 200 first baseline trials revealed a mean horizontal gain increase of 53% for one participant and 21% for the other participant. We conclude that saccades are operant behavior that may be reinforced by the ability to perform visual discrimination tasks.

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43.4093 Saccade latencies in an overlap paradigm when manipulating the stimuli timing, energy and transient changes.

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Previous studies showed that a temporal overlapping of the fixation-target with the saccade-target onset induces a shift of saccade reaction time distributions towards longer values. Here we present a series of experiments probing how an overlap paradigm, combined with the manipulation of stimuli durations, energy and transient changes might modulate saccadic reaction time distributions. We recorded saccadic reaction time in four participants in six experiments in which a saccade-target appeared at a ran-

Monday AM

dom amplitude after a fixation period. First we parametrically manipulated the duration of the overlap using a range of intervals (from 0 to 200 ms). In a second experiment we probed the interaction of various foreperiod intervals (i.e. the duration of the fixation period prior to saccade-target onset) and overlap using two overlap intervals (20 or 140 ms). In two additional experiments we manipulated either the stimuli sizes or their contrasts in overlap paradigms (20 or 140 ms). Lastly, we introduced a visual transient during the overlap interval via two manipulations (both with a range of SOA): either a distractor ring appeared around the fixation-target, or dynamic random noise replaced the fixation-target. Results show reliable modifications in the latency distributions depending on the overlap interval as well as idiosyncratic differences. Furthermore, all our additional experimental manipulations also affected the latency distributions revealing strong interacting inhibitory processes. We conclude that the effects of overlap intervals may combine with the influence of other stimuli properties to produce strong effects on decision process.

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43.4094 **Parallel and continuous visuomotor processing of simultaneously moving targets** Laurent Goffart[1](laurent.goffart.int@gmail.com); [1]INT, CNRS Aix-Marseille Université, Marseille, France

When two static visual targets are sequentially presented, the saccades with the shortest latencies land on the location of the first target whereas the later saccades land closer to the second one. The transition between these two locations is not abrupt but gradual and continuous. When the targets are simultaneously presented, the saccades land on locations situated along a line connecting them (averaging). The process specifying the oculomotor goal was further explored in three monkeys by testing the saccades made in response to two centrifugal targets moving simultaneously in different directions. After the fixation of a central target for a variable interval, two trial conditions were intermixed. During the single-target trials, the target moved toward the periphery along the cardinal (horizontal, vertical) or oblique axis. During the double-target trials, the central target was replaced by two identical targets moving centrifugally with equal or different speeds. One target moved along an oblique axis while the other moved along a cardinal axis. The monkeys were free to track anyone of the two targets or anywhere between, and were rewarded on every trial. During the double-target trials, the first saccade endpoints were scattered in the field situated between the target paths. Although their distribution was biased toward the slower target, the orientation of the scatter depended upon the location and speed of the two targets: the endpoints were scattered between lines of isochronous target locations. Following the "averaging" saccade, the eye moved slowly in the same direction for duration which could exceed 300ms. The use of accelerating and decelerating targets revealed curved saccades, with early and later parts of their trajectory biased by the slowest target. This work demonstrates that the visual signals from two moving targets are processed in parallel with high spatiotemporal resolution, and that they continuously drive the oculomotor system.

Acknowledgement: ERC Position (headed by Pr. Patrick Cavanagh)

43.4095 **An orchestra without a conductor: Saccadic visual exploration can be explained by a self-paced process** Shlomit Yuval-Greenberg[1,2](shlomitgr@tau.ac.il), Roy Amit[2], Izhar Bar-Gad[3]; [1]School of Psychological Sciences, Tel Aviv University, [2]Sagol School of Neuroscience, Tel Aviv University, [3]The Leslie and Susan Goldschmied (Gonda) Multidisciplinary Brain Research Center, Bar Ilan University

Background: Sensory organs are thought to sample the environment rhythmically thereby providing periodic perceptual input. Some sensing behaviors, such as rodents' whisking, are governed by central oscillatory generators which impose rhythms on the motor control of sensory acquisition and consequently on sensory input. Saccadic eye-movements are the main visual sampling mechanism in primates, and were suggested to constitute part of such a rhythmic exploration system. The temporal dynamics of saccades determine the flow of visual input and so explaining what governs them is vital for understanding vision. The purpose of the present study was to examine whether saccade properties are consistent with an oscillatory generator or whether they can be more parsimoniously explained by a self-generating first-order process. Methods: Eye-movements were tracked while observers were either free-viewing a movie or fixating a static stimulus. We inspected the temporal dynamics of exploratory and fixational saccades using methods derived from spike-train analysis. The first- and high-order dependencies within saccade sequences were examined through a statistical interval-shuffling procedure. We tested our data against a mathematical model to demonstrate that first-order dependencies can fully account for the observed saccade dynamics. Results: The findings show that saccade timings can be fully and parsimoniously explained by a self-generating mechanism. The temporal dynamics of saccadic events are explained by first-order dependency features, and mainly by the post-saccadic inhibition period. The proposed mathematical model contains only first-order dependencies and nevertheless captures the various facets of saccade timings. Conclusion: Saccades are different than other exploratory systems, such as whisking or sniffing. Unlike those exploratory systems, which were shown to be driven by central oscillations, saccades can be more parsimoniously explained as a self-driven process. This is a first step toward examining whether saccade dynamics could be a source rather than a consequence of rhythm injected into the visual cortex.

Acknowledgement: This work was funded by the Israel Science Foundation (ISF) grant 1427/14.

43.4096 **Dissociable effects of stimulus capture, global effect and task intention in saccade targeting** David Aagten-Murphy[1](david.aagtenmurphy@gmail.com), Paul Bays[1]; [1]Department of Psychology, University of Cambridge

Saccadic eye-movements enable us to rapidly direct our high-resolution fovea onto relevant parts of the visual world. However, while we can intentionally select a location as the target for a saccade, the wider visual scene also influences the executed movement. In the presence of multiple objects, eye-movements may be "captured" to the location of a distractor object, or biased towards the intermediate position between objects (the "global effect"). Here we examined how the relative strengths of the global effect and visual object capture changed as a function of saccade latency and the separation between items. Importantly, while many previous studies have failed to give explicit instructions to observers, we instructed our participants either to saccade to a specified target object or to the midpoint between the two stimuli. This allowed us to examine how the explicit movement goal influenced the tendency for saccades to terminate at target, distractor, or intermediate locations. Using a probabilistic mixture model, we found evidence that both visual object capture and the global effect co-occurred at short latencies and declined as latency increased. As separation between the objects increased, capture came to dominate the landing positions of fast saccades, with reduced global effect. Critically, instructions substantially altered the distribution of saccade landing points, even at the shortest latencies. By comparing the model fits across the two tasks we could separately estimate the proportion of saccades unwantedly captured by either global or stimulus locations. This allowed us to dissociate the two different types of automatic capture from the influence of goal-directed processes. Overall, these results suggest that previous studies may have overestimated the role of automatic processes in determining saccade endpoints by confounding the influences of stimulus capture, global effect, and goal-directed processes on saccade landing distributions.

43.4097 **How quickly can color information drive reflexive saccadic eye movements?** Amandeep Kaur[1](akaur002@citymail.cuny.edu), Jay Edelman[1,2]; [1]Dept. of Biology, The City College of New York, [2]Biology Doctoral Program, The City University of New York

Recent work from this laboratory has indicated that reflexive saccadic eye movements (including express saccades – reaction times < 120 msec) can be influenced by cognitive commands expressed in object-centered coordinates without an accompanying increase in reaction time (Edelman et al, 2007; Edelman et al, in press). We wished to examine whether color information could similarly influence reflexive saccades without increasing reaction time. Two subjects trained to make short reaction time saccades (>= 50% express) made saccades in a reflexive target/non-target task in which target was indicated by the color of the fixation point. Subjects viewed the fixation point for 500-800 msec. Two visual stimuli (1 deg sq), one red and one green, appeared at 10 deg eccentricity from the fixation point, separated in polar angle by 30 deg. Stimuli were centered randomly either to the left or right of the fixation point. The topmost stimulus was red (green) randomly on 50% of trials. The color of the fixation point (i.e.

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the instruction) varied randomly from trial to trial. To increase variability in RT, the time between fixation point disappearance and target appearance was varied (between 150 msec overlap and 150 msec gap). Subjects were instructed to make saccades to the color-defined target as soon as the stimuli appeared. Data indicated that while the vectors of express saccades were not influenced by the color instruction, with a mean landing point in between the target and non-target, saccades just at the boundary of the express range (120-130 msec) were affected significantly. Reaction time was not increased relative to one-target control trials. Additional experiments are examining whether task training and blocked trial instructions could enhance the effect of instruction on saccade vector.

Acknowledgement: 5G12MD007603-30

43.4098 The Spatial Separation of Movement Goals and Preparation Time Determines Single vs. Averaged Saccade Motor Plans

Shane Kelly[1](skelly18@masonlive.gmu.edu), Matthew Peterson[1], Wilsaan Joiner[1]; [1]George Mason University

Motor program theory assumes that control resides over abstract representations of actions (programs or plans), and that a plan is selected and executed during voluntary movement (Adams, 1971). However, when the goal between two potential targets is ambiguous, the motor output is distinct from movements made to a single goal. These movements are often called averaged or intermediate movements because the output resembles a combination of the two possible plans. This pattern of behavior is observed for quick eye movements (saccades). When two visual targets are presented in close proximity the eyes tend to land in between the two (saccade averaging, the global effect; Coren & Hoenig, 1972). Although saccade averaging is typically observed when the stimuli are close and the eye movements are made with little preparation time, the exact spatial and temporal conditions in which two saccade motor plans are averaged is undefined. Recently, Haith and colleagues (2015) examined averaged movements during a time restricted visually guided reaching task. The target shifted a variable distance and at different times before reach onset, providing limited time to re-prepare the movement plan. Here, we applied the same paradigm and framework to saccadic eye movements. In addition, to confirm when more than one motor plan is output, we created two models to compare to our observed data. One model assumed averaging and the other assumed only one motor plan could be executed at a given time. We tested subjects with target displacements of 20, 30, 40, 60, and 90 degrees of separation. Using Bayesian model comparisons, our results demonstrate that averaging of two saccade plans occurs during a specific temporal range when the displacement between potential targets is small (20, 30, 40), but across the entire temporal range, only one motor plan is output at the larger displacements (60 and 90).

43.4099 Saccade-contingent feedback improves eye movement efficiency

Preeti Verghese[1](preeti@ski.org), Saeideh Ghahghaei[1]; [1]The Smith-Kettlewell Eye Research Insitute

We have shown previously that when observers have to find multiple targets in a limited time, immediate feedback following each saccade leads to efficient saccades (Verghese & Ghahghaei, 2013). Here we examine whether feedback is as effective when it occurs at the end of the trial, rather than after each saccade. Observers actively searched a display with six disks that each had an independent probability of being a target, so the number of targets in a trial ranged from 0 to 6. The probability of the target was set to 0.33, 0.5 or 6.7 in separate blocks. The luminance of each disk was drawn randomly from a Gaussian distribution for target and distractor luminance. Due to the overlap of these distributions, it was uncertain whether a luminance value in the overlap zone came from the target or distractor distribution. Because there was insufficient time to inspect all locations, selecting uncertain locations was much more informative than selecting locations most likely to have the target. As an incentive to explore uncertain locations, a saccade to a disk with luminance in the overlap zone generated feedback by switching the disk luminance to the mean value of the "true" distribution. The feedback occurred either immediately after the saccade, or at the end of the 900 ms trial, and lasted 200 ms. Six observers participated in the experiment, with separate sessions of delayed and immediate feedback, in counterbalanced order. Observers made more efficient saccades in sessions where feedback occurred immediately after a saccade, compared to delayed feedback at the end of the trial, particularly when target probability was high and multiple targets were more frequent. Accuracy was also higher in sessions with immediate feedback. These findings indicate that saccade-contingent feedback is very effective in increasing the efficiency of eye movements in visual search.

Acknowledgement: Pacific Vision Foundation, Smith-Kettlewell Eye Research Institute

43.4100 Intrinsic vs extrinsic value in saccadic adaptation

Annegret Meermeier[1,2](a_meer05@uni-muenster.de), Svenja Gremmler[1], Markus Lappe[1,2]; [1]Department of Psychology, University of Muenster, [2]Otto Creutzfeldt Center, University of Muenster

Saccadic adaptation is a learning process that maintains the accuracy of eye movements to ensure effective perception of the environment. It is usually studied by shifting the target mid-flight during the saccade to introducing a consistent error to the visual system. In a prior study (Meermeier et al., J.Vis., 2016) we found that saccadic adaptation is stronger when human pictures are used as targets in comparison to noise stimuli. We attribute this difference to an intrinsic value in pictures of humans, and to a sensitivity of the saccadic system to the value of the target. To investigate whether a modulation of acquired extrinsic value could elicit the same effect, we compared saccadic adaptation towards high value and low value targets in expert players of the video game 'Candy Crush Saga'. As targets we chose 3x4 item-patterns that either allowed for a very rewarding move (high value targets) or that did not allow any rewarding move (low value targets). All other procedures matched the study by Meermeier et al. (2016). Twenty-eight subjects participated in two sessions of scanning outward adaptation. We computed saccadic amplitude change for the last 40 trials of a 200 trial adaptation phase. Amplitude change was 12.7% for the high value and 13.1% for the low value targets. Bayesian repeated measures Anova revealed evidence for the Null hypothesis (BF01 = 4.822) indicating that saccadic adaptation did not differ according to the extrinsic value of the target. A subsequent control experiment using human figures as stimuli again confirmed their effectiveness to modulate saccadic adaptation. We thus conclude that it is rather the intrinsic value of the image and maybe its social component that induces stronger saccadic adaptation.

43.4101 Effect of reinforcement on the size-latency phenomenon

Cécile Vullings[1](cecile.vullings@gmail.com), Mark Harwood[2,3], Laurent Madelain[1,4]; [1]Univ. Lille, CNRS, CHU Lille, UMR 9193 - SCALab - Sciences Cognitives et Sciences Affectives, F-59000 Lille, France , [2]Department of Biology, City College of New York, City University of New York, NY, USA, [3]Department of Psychology, University of East London, UK , [4]Aix Marseille Université, CNRS, Institut de Neurosciences de la Timone, UMR 7289, Marseille, France

Saccadic latencies are known to change as a function of target eccentricity and size. Recently, it has been shown that latencies may be evaluated in terms of the amplitude of the step in proportion to the size of the target, and consistently change according to this step-size ratio (Madelain et al., 2005; Harwood et al., 2008; De Vries et al., 2016). This effect, called the size-latency phenomenon, might be seen as a function of a cost-benefit relationship: the difference in latencies might be explained by the 'cost' of making a saccade while the target mostly remains within the attentional field. Here, we probe this hypothesis by manipulating the cost-benefit relationship using a reinforcement procedure. Three subjects (including two authors) tracked a visual ring target stepping horizontally with an amplitude ranging from 1.2 to 10.5 deg. The size (diameter) of the ring varied as a function of the target step such that the step-size ratio was equal to either 0.3 or 1.5. Trials with saccadic latencies outside a [80;500] ms range or saccadic gain outside [0.5;2] were discarded. We used a dynamic reinforcement criterion based on the median computed over a 50-trial moving window in 2 blocked conditions. In the 0.3 ratio condition, any latency shorter than the criterion was reinforced. In the 1.5 ratio condition, any latency longer than the criterion was reinforced. During baseline, we observed the size-latency phenomenon with large differences in latencies depending on the ratio in force (e.g. 164 ms and 285 ms, respectively for 1.5 and 0.3). After training (4800 reinforcement trials), distributions shifted toward the shorter or longer value (e.g. 418 ms and 184 ms, respectively for 1.5 and 0.3). Our results indicate that reinforcement contingencies can considerably affect saccadic latency distributions, and support the idea of a cost-benefit evaluation for saccade triggering.

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43.4102 **The necessity to choose causes effects of reward** Christian Wolf[1](chr.wolf@uni-marburg.de), Anna Heuer[1], Anna Schubö[1], Alexander Schütz[1]; [1]Allgemeine und Biologische Psychologie, Philipps-Universität Marburg, Marburg, Germany

Humans can maximize reward by choosing the option with the largest expected value (probability × magnitude of reward). Expected value is taken into account for the preparation of saccadic eye movements, as latencies to single-targets are negatively correlated with expected value (Milstein & Dorris, 2007). Here we show that this relationship only holds when responses to single targets are embedded in a context where participants sometimes have to choose between different options. Participants were rewarded differently for saccades to targets appearing to the left or right from fixation. In any trial, either one less or highly rewarded target (single-trial) or two targets (choice-trial) were displayed. In choice-trials, participants had to decide for one of the two targets and received the corresponding reward. We show that in single-trials, saccade latencies to the less rewarded target were elevated only when choice-trials were present. This effect increased with the amount of choice trials within a block. When changing the reward congruency between choice- and single-trials, single-trial latencies only depended on which target was preferred in choice-trials but not on the single-trial reward, showing that choice-trials causally determined the latency delay. Two further experiments emphasize the functional role of this delay: First, its magnitude scaled with the difficulty to make a reward-maximizing response in choice-trials. Second, it was reduced when single-trials were cued in advance. Moreover, fitting the LATER model (Carpenter & Williams, 1995) implied that prolonged latencies to the less rewarded target are caused by a reduced baseline activity in the decision signal. Taken together, our results suggest that there is no direct connection between expected value and saccade preparation. Instead, expected value affects latencies only when there is a functional reason to do so, for instance when participants have to choose between options differing in expected value.

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TUESDAY MORNING TALKS

FACE PERCEPTION: EMOTION AND MODELS

Tuesday, May 23, 8:15 - 9:45 am
Talk Session, Talk Room 1
Moderator: James Tanaka

51.11, *8:15 am* **The effects of emotional cues on visual perception and the special case of faces** Batsheva Hadad[1](bhadad22@gmail.com), Elite Mardo[1], Galia Avidan[2]; [1]Edmond J. Safra Brain Research Center Faculty of Education University of Haifa, [2]Department of Psychology Ben Gurion University of the Negev

Ample evidence suggests that emotion affects visual perception. The nature and the mechanism underlying these effects, however, are unclear. One of the more prevailing accounts suggests that during perception, arousal biases competition in favor of perceptually conspicuous or goal-relevant stimuli. In the first set of experiments directly testing this hypothesis, we demonstrate that negatively arousing pictures impaired subsequent discrimination of visual stimuli such as cars. However, face discrimination remained relatively persevered, particularly in individuals with high trait anxiety. To uncover the mechanism underlying these preserved face representations, Posner's cuing task was used in which arousing pictures served as either valid or invalid spatial cues. Faster RTs (benefit) to stimuli succeeding a valid cue and slower RTs (cost) to stimuli succeeding an invalid cue were always observed when the cue was neutral. However, for a negatively arousing cue, cost was observed for cars but not for faces. Interestingly, cost effects following an exposure to the invalid emotional stimuli were highly correlated with trait anxiety such that reduced cost was exhibited during face discrimination for anxious individuals. These results indicate that arousal biases attention towards perceptually salient stimuli, allowing observers, particularly those with high trait anxiety, to disengage attention from an arousing stimulus more easily when it is followed by a face. Altogether, the results indicate that exposure to emotional visual stimuli is detrimental to the perception of subsequently presented neutral stimuli. However, high priority stimuli, such as faces, are more resilient to arousal-biased competition, capturing attention that enhances their processing.

Acknowledgement: ISF grant to Batsheva Hadad #967/14

51.12, *8:30 am* **Angrier = Blacker?: The influence of emotional expression on the representation of race in faces, measured with serial reproduction** Stefan Uddenberg[1](stefan.uddenberg@yale.edu), Brian Scholl[1]; [1]Department of Psychology, Yale University

In principle, race and emotional expression are orthogonal dimensions of face perception. But psychologically, they are intertwined — as when racially ambiguous faces are judged to be angrier when categorized as Black than when categorized as White. Does this reflect superficial judgmental biases, or deeper aspects of how faces are perceived and represented? We explored this using the method of serial reproduction, where visual memory for a briefly presented face is passed through 'chains' of many different observers. Here, a single face was presented, with its race selected from a smooth luminance-controlled continuum between White and Black. Each observer then completed a single trial, in which they reproduced that face's racial identity by morphing a test face along the racial continuum. Critically, both the initially presented face and the test face could (independently) have an Angry or Neutral expression, which the observer could not change. Within each chain of observers, these expressions were held constant, while the race of the face initially seen by each observer was determined by the previous observer's response. The chains reliably converged on a region well within White space, even when they started out near (or at) the Black extreme — as observers' representations were pulled toward a 'default attractor' in the White region of the face space. Strikingly, however, there was a single situation when this pattern reliably reversed: when observers were shown an Angry face and tested on a Neutral face, chains converged instead on a region well within the Black region. This is exactly the pattern that is predicted if Angry faces are misremembered as Blacker than the equivalent Neutral faces (since the effect cancels out when both faces are Angry). These results illustrate how irrelevant stereotype-consistent information can influence face representations in a deep way, which may have important real-world implications.

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51.13, *8:45 am* **Perceptual inference of dynamic emotion in natural movies** Zhimin Chen[1](mandy_chen@berkeley.edu), David Whitney[1]; [1]Department of Psychology, University of California, Berkeley, Berkeley, CA, USA

Emotion recognition is a critical function of vision. It seems intuitive that to perceive a person's emotions, we just need to focus directly on that person—their face or body. However, sometimes the context in which a person has an emotion may be key to understanding that emotion. Can a person's emotion be dynamically inferred from contextual visual information, even without face and body-related information? We tested the ability to infer and track the emotions of people based solely on visual situational context, without any information about facial expression. Thirty-one observers watched silent movie clips of two characters interacting. The face and body of a randomly chosen character were occluded (target); the other character in the movie clip (partner) remained visible. Observers tracked the inferred emotion of the masked (invisible) target and reported the emotion by moving a mouse pointer in a valence-arousal (2D) space continuously, in real-time. Baseline ratings of the target and partner characters were established by asking a separate group of 69 observers to track the target's emotion when all characters were visible (unoccluded). In the baseline, observers agreed strongly when tracking the visible target's emotion (mean Cronbach's alpha = 0.95). More importantly, observers accurately inferred and tracked the emotion of the invisible target character, when compared to the baseline (mean Spearman's rho = 0.58, $p < .01$; mean absolute deviation = 8.5%). Cross-correlation analyses showed that inferring emotion based on context alone was as fast as tracking emotion using face and body information (no significant non-zero time lag). More strikingly, observers inferred the intensity of the target's emotion (arousal) accurately by using contextual ensemble information, not simply by tracking the partner's arousal (partial correlation = 0.42, $p < .01$). Our results demonstrate that observers can infer and track emotion accurately and speedily in real time based entirely on contextual information.

51.14, *9:00 am* **Unconsciously attracted: invisible attractive faces orient visual attention.** Shao-Min (Sean) Hung[1](konaes@gmail.com), Chih-Hsuan Nieh[2], Po-Jang (Brown) Hsieh[1]; [1]Neuroscience and Behavioral Disorders Program, Duke-NUS Medical School, Singapore, [2]Department of Psychology, National University of Singapore

Past research has proven human's extraordinary ability to extract information from a face in the blink of an eye, including its emotion, gaze direction, and attractiveness. However, it remains elusive whether facial attractiveness can be processed and influences our behaviors in the complete absence of conscious awareness. Here we demonstrate unconscious processing of facial attractiveness with three distinct approaches. In Experiment 1, the time taken for faces to break interocular suppression was measured. The results showed that attractive faces enjoyed the privilege of breaking suppression and reaching consciousness earlier. In Experiment 2, we further showed that attractive faces had lower visibility thresholds, again suggesting that facial attractiveness could be processed more easily to reach consciousness. Crucially, in Experiment 3, a significant decrease of accuracy on an orientation discrimination task subsequent to an invisible attractive face showed that attractive faces, albeit suppressed and invisible, still exerted an effect by orienting attention. This effect disappeared with inverted faces, suggesting that it was not driven by low-level local facial features. Taken together, for the first time, we show that facial attractiveness can be processed in the complete absence of consciousness, and an unconscious attractive face is still capable of directing our attention.

51.15, *9:15 am* **Mooney Faces from Photos** Tsung-Wei Ke[1,2](twke@icsi.berkeley.edu), Stella Yu[1,2], David Whitney[1]; [1]UC Berkeley, [2]International Computer Science Institute

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Mooney faces are simply black and white pictures that human subjects can still effortlessly recognize as a face, along with many attributes such as age, gender, and facial expressions. How such a remarkable ability is achieved with so little information is key to understanding human visual recognition. However, a very basic question is what makes a Mooney face, as not every binarized face image appears as a Mooney face. Current Mooney face generation is ad-hoc, requiring manual grayscale image editing and human subjective judgment, a time and labor-consuming process. Our goal is to generate Mooney faces from photos automatically. We take a deep learning approach based on very limited Mooney faces but many more face and non-face photos. We first train a gray-scale face classifier using FaceScrub images (91,712 faces, 630 identities) as positive examples and random ImageNet samples (91,712 images, 1000 classes) as negative examples. We then train a black-white Mooney face classifier by fine-tuning the grayscale model on both thresholded face/nonface images and a small training set of Mooney face images. We assume that any non-face images, thresholded at any level, positive or negative, should be classified as non-faces, whereas face images should be classified as Mooney faces only in positive but not in negative contrast. Such instances are generated in balanced mini-batches to train our Mooney face classifier. Given a grayscale face image, we generate a set of two-tone versions by smoothing and thresholding the image with a range of parameters. The highest scoring image predicted by our Mooney face classifier becomes the Mooney face. If the highest score is below probability 0.5, we reject the Mooney face and declare the grayscale image unfit as a Mooney face candidate. This approach yields a large-scale Mooney face dataset, potentially useful for future computer vision, psychophysics, and neurophysiology experiments.

51.16, *9:30 am* **Objective Analysis of the Subjective Information Contents of Memory of Familiar Faces** Jiayu Zhan[1](j.zhan.1@research.gla.ac.uk), Nicola Van Rijsbergen[1,2], Oliver Garrod[1,2], Philippe Schyns[1,2]; [1]School of Psychology, University of Glasgow, [2]Institute of Neuroscience and Psychology, University of Glasgow

Humans identify faces by matching real-world visual information with memorized identity information. However, there is no direct access to the information contents of human memory. Here, we address this challenge by reverse correlating the memory contents of familiar face identities using a novel generative model of face identity information. We applied a General Linear Model (GLM) on 355 3D faces, independently for shape and texture, to explain away the variance of gender, ethnicity and their interactions, isolating the multivariate identity information represented as residual deviation from the norm, independently for 3D shape and 2D texture. Next, with Principal Components Analysis (PCA) we parameterized the identity residuals as 355-dimensional PCA weights. Our experiment probed the memory contents of 4 face identities familiar to 14 observers. We generated "identity noise" for each familiar face. To illustrate, when the target was "Mary" we added randomly assigned PCA weights (the identity noise, S1-A) to the local norm. On each trial, participants viewed 6 random identities, chose the most similar to "Mary" and rated this similarity (S1-A). From the 1,800 trials pairings < face identity information; similarity score> we linearly regressed per participant the shape and texture information that modulates similarity choices. The resulting classification faces are shown in S1-B1 and S1-B2. We further analysed the fit between the objective ground truth identity information and memory contents. Results show that participants memorized "Mary" using a consistent set of features. Faithful features are the most objectively distant from the norm in the ground truth. Caricatured and imagined features occur for vertices objectively nearer the norm in ground truth. Our results are compatible with a norm-based account of identity coding in memory (S1-B), but the objectively distant features are not necessarily memorized (S1-C), suggesting semantic biases in feature selection.

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Eye Movements: Fixation and perception

Tuesday, May 23, 8:15 - 9:45 am
Talk Session, Talk Room 2
Moderator: Scott Watamaniuk

51.21, *8:15 am* **Fixations on real objects are affected by affordance and the ability to act** Tom Foulsham[1](foulsham@essex.ac.uk), Marcello Costantini[1]; [1]Department of Psychology, University of Essex

A range of recent studies have examined how fixations are allocated to pictures containing real world objects. Observers show both optimal and preferred viewing positions on such images, which may reveal how our attention is deployed in complex stimuli. However, there are far fewer studies investigating fixations during interactions with actual objects, despite classic and contemporary evidence that gaze in real-world tasks is largely driven by the demands of motor actions. In two experiments, we describe the distribution of fixations made when participants view real world, graspable objects such as tools. In Experiment 1, participants reached to pick up a series of such objects and gaze locations were mapped onto a standard reference image. The targets for gaze were affected by the orientation (and therefore the affordance) of the object and by the handedness of the observer, as well as by the timecourse of a reaching action. Participants' fixations were guided towards handles and grasp points for the upcoming movement. In Experiment 2, participants viewed real objects under controlled conditions and without performing an action. Visual attention to these objects was constrained by body posture, such that participants who were unable to act (because their hands were tied) showed different gaze patterns. Thus visual attention to the affording and functional parts of objects depends on the capability to act. These findings qualify recent results from picture viewing, and provide a bridge to studying complex everyday tasks.

51.22, *8:30 am* **Intra-saccadic motion streaks as a cue to the localization of objects across eye movements** Richard Schweitzer[1,2,3](richard.schweitzer@hu-berlin.de), Martin Rolfs[1,2]; [1]Bernstein Center for Computational Neuroscience Berlin, Germany, [2]Department of Psychology, Humboldt-Universität zu Berlin, Germany, [3]Berlin School of Mind and Brain, Humboldt-Universität zu Berlin, Germany

Saccades shift objects across the retina at high velocities, yet we never perceive the blurred motion streaks that any object in the scene should cause. It is widely assumed that intra-saccadic motion signals are suppressed to preserve stable perception of the world. Using a projection system with sub-millisecond temporal resolution, we investigated the alternative hypothesis that intra-saccadic motion streaks serve a functional role in the localization of objects across saccades. Observers made horizontal saccades of 16 degrees of visual angle (dva) towards a target stimulus (a noise patch of high or low spatial frequencies), which—during the saccade—moved up or down by 4 dva at high speeds (240 to 950 dva/s). A second, identical distractor stimulus appeared after movement completion at the mirror location (below or above the initial target location), and observers were asked to locate the original stimulus that had undergone continuous motion. In Experiment 1, these stimuli were present directly after movement offset; in Experiment 2, we introduced a blank to alleviate post-saccadic masking. Moreover, both experiments involved a replay condition, in which the target moved across the screen according to the participants' own eye movements recorded in saccade trials, thus, simulating the retinal motion produced during saccades. Without blanking, stimulus localization performance was considerably lower in saccade trials than during replay. In contrast, with blanking, performance was comparable during saccades as during replay: Observers reliably localized targets even for the highest intra-saccadic stimulus speeds, and performance increased with slower speeds. Importantly, across all conditions, targets of low spatial frequencies were consistently discriminated more accurately than high spatial frequencies. These results suggest that intra-saccadic motion signals—in particular of low spatial frequencies—can serve as visual cues to localize objects across saccades. Saccadic masking appears to be sufficient to prevent these signals from reaching conscious awareness.

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51.23, *8:45 am* **The frequency of catch-up and micro saccades reacts to and predicts stimulus events** Stephen Heinen[1](heinen@ski.org), Jeremy Badler[1], Scott Watamaniuk[2,1]; [1]The Smith-Kettlewell Eye Research Institute, San Francisco, CA, [2]Wright State University, Dayton OH

Smooth pursuit and fixation are generally regarded as independent systems. But are the small saccades that occur during pursuit (catch-up saccades) and the small saccades that occur during fixation (microsaccades) generated by different mechanisms? Here we test this by capitalizing on the curious phenomenon that microsaccades subside around the time of visual events. Subsidence occurs either in reaction to a visual cue or in anticipation of a task-relevant stimulus. During anticipatory subsidence, saccades almost completely stop. We ask if a similar phenomenon occurs for catch-up saccades during ocular pursuit. Observes pursued a linear array of 15 small alphanumeric characters (0.28° × 0.5°) and performed a character discrimination task on them (Lovejoy et al., 2009). A linear array of '8's appeared stationary for a random fixation duration, then translated either leftward or rightward across the screen at 8°/s, 12°/s or 16°/s for 1640–2440 ms. The pursuit target was always the middle character of the array, which was cued 320 ms after fixation onset. Following the fixation period, at a random time (1040–1440 ms), the character array changed from '8's to '2's and '5's except for a single probe character that changed to a '3' or an 'E'. After 200 ms, all characters changed back to '8's. Observers identified the '3' or 'E' with a keypress. We found that catch-up saccade frequency decreased following the pursuit target cue, and also in anticipation of the identification task. The time course of the reactive and anticipatory subsidence was virtually identical during pursuit and fixation. The results provide evidence that the mechanism generating catch-up saccades during pursuit also generates microsaccades during fixation. We hypothesize that small saccades subside during pursuit and fixation to allow clear vision when high acuity is required.

Acknowledgement: NIH-1R01EY021286

51.24, *9:00 am* **The Role of Microsaccades in the Snellen Acuity Test** Janis Intoy[1](jintoy@bu.edu), Michele Rucci[1, 2]; [1]Graduate Program for Neuroscience, Boston University, [2]Department of Psychological and Brain Sciences, Boston University

Standard tests of visual acuity are commonly taken to measure limits in visual resolution imposed by the optical and physiological properties of the eye and retina. However, previous studies have shown that performance in high-acuity tasks also depends on fixational eye movements (FEM), the small eye movements that humans perform even when attending to a selected location. FEM contribute both by transforming spatial information into temporal transients [Rucci et al., 2007] and by precisely positioning a preferred retinal locus on the stimulus of interest [Ko et al., 2010]. These previous findings suggest that the results of standard tests of visual acuity also depend upon oculomotor activity. Here we investigated the function of microsaccades in the Snellen eye-chart test, the most common test of visual acuity. We recorded eye movements in human observers as they identified the optotypes of the 20/20 line of a tumbling-E eye chart designed to fit within the foveola, the small region (~1o in diameter) of the retina with the highest cone density. Eye movements were recorded with a Dual Purkinje Image eye-tracker, a system with high spatial and temporal resolution. We show that microsaccades are tuned to the task during the Snellen test. Microsaccades are smaller and slightly less frequent than during sustained fixation and are used to precisely shift gaze across optotypes. When optotypes were stabilized on the retina by counteracting the consequences of eye movements, their size had to be increased by 0.15 logmar to recover the normal level of performance. These findings demonstrate that the outcome of a Snellen test incorporates contributions from fixational eye movements and that visual acuity deficits may originate from poor oculomotor control.

Acknowledgement: Supported by NIH R01 EY018363 and NSFgrants BCS-BCS-1457238 and 1420212.

51.25, *9:15 am* **Visual suppression within the foveola during microsaccades** Michele Rucci[1,2](mrucci@bu.edu), Naghmeh Mostofi[1]; [1]Department of Psychological and Brain Sciences, Boston University, [2]Graduate Program in Neuroscience, Boston University

Much research has focused on the transient reduction in visual sensitivity that occurs around the time of saccades, a phenomenon known as saccadic suppression. While it is well established that visual thresholds increase before and during a saccade, it remains unclear whether this phenomenon extends to microsaccades, the very small saccades that keep the retinal projection of the attended stimulus within the high-acuity foveola. Previous studies focused on how microsaccades affect the visibility of peripheral stimuli during sustained fixation. However, it is now clear that humans use microsaccades to explore fine detail (Ko et al, 2010), and a critical question is how microsaccades affect the visibility of stimuli within the foveola. Here we measured sensitivity to contrast changes in a search task designed to model primate's social grooming, a task that naturally led to frequent microsaccades. Observers searched for fleas (the targets) in a naturalistic noise field that also contained dust particles (the distractors). Both targets and distractors were 5′ dots, but targets transiently revealed themselves by changing contrast (a flea jump; a 10 ms pulse), which the observer reported by pressing a button on a joypad. A high-resolution gaze localization technique (Poletti et al, 2013) and synchronization of contrast pulses with microsaccades enabled precise spatiotemporal stimulation of selected regions within the foveola. We show that a strong suppression in foveal sensitivity occurs at the time of microsaccades. At all tested eccentricities within the foveola, suppression starts ~50 ms before microsaccade onset and is followed by an enhancement in visual sensitivity immediately after microsaccade end. Contrast sensitivity also decreases rapidly within eccentricity within the foveola, so that a considerable increment in threshold can already be observed at only 15′ eccentricity. These results show that microsaccades profoundly affect visibility at the very center of gaze.

Acknowledgement: NIH grant R01 EY018363, NSF grants BCS-BCS-1457238 and 1420212

51.26, *9:30 am* **Rhythmic modulation of human visual sensitivity synchronized with planning of saccades** Maria Concetta Morrone[1,2,3](concetta@in.cnr.it), Alessandro Benedetto[1,4]; [1]Department of Translational Research on New Technologies in Medicines and Surgery, University of Pisa, Via San Zeno 31, 56123 Pisa, Italy, [2]Institute of Neuroscience, National Research Council (CNR), 56124 Pisa, Italy, [3]Scientific Institute Stella Maris, Viale del Tirreno 331, 56018 Calambrone, Pisa, Italy, [4]Department of Neuroscience, Psychology, Pharmacology and Child Health, University of Florence, 50135 Florence, Italy

Tommasini et al (2015) have shown that voluntary hand movements can induce rhythmic theta-band oscillations in visual contrast sensitivity, a very early visual function, and crucially for stimuli irrelevant to the executed action. The oscillations emerge during the motor planning stage, before the onset of the reaching and grasping movement. Action planning for eye movements and perception are intimately coupled systems. The temporal synchronization between saccadic onset and saccadic suppression is a clear demonstration of this temporal precise link. However, how the brain achieves this close synchronization is still unknown. We investigated the effect of saccades on contrast discrimination sensitivity over a long period stretching over more than 1 second before and after saccade execution. Human subjects made horizontal saccades at will to two stationary saccadic targets separated by 20° degrees. At a random interval, a brief Gabor patch was displayed between the two fixations in either the upper or lower visual field, and the subject had to detect its location. Strong saccadic suppression was measured between −50 and 50 ms from saccadic onset. However, the suppression was systematically embedded in a trough of oscillations of contrast sensitivity and criterion that fluctuated rhythmically in the delta range (at about 3 Hz), commencing about one second before saccade execution and lasting for up to one second after the saccade. The results show that saccadic preparation and oscillations in visual sensitivity are coupled, and the coupling might be instrumental in temporally aligning the initiation of the saccade with the visual suppression.

Acknowledgement: This work was supported by ERC-FP7 ECSPLAIN (grant no. 338866) to M.C.M.

Tuesday AM

Visual Search: Attention

Tuesday, May 23, 10:45 am - 12:30 pm
Talk Session, Talk Room 1
Moderator: Joy Geng

52.11, *10:45 am* **Individual differences in susceptibility to irrelevant environmental influences predict visual search performance**

Michelle Kramer[1](kramerm@gwu.edu), Rachel Wynn[1], Stephen Mitroff[1]; [1]The George Washington University

Often it is vital to process currently relevant information while resisting task-irrelevant influences. For example, radiologists must focus on their current patient's images while blocking out the previous patient's details. It is intriguing to consider that certain individuals are more susceptible to task-irrelevant environmental biases, and how such biases could influence visual search performance. To investigate, data were analyzed from the mobile application Airport Scanner (Kedlin Co., www.airportscannergame.com), a game wherein users assume the role of airport security officers searching simulated x-ray luggage for prohibited items. In a mini-game following each level, players were to quickly sort individual items as either prohibited or allowed. Critically, in any given mini-game, prohibited items appeared with a 25%, 50%, or 75% probability. Susceptibility to environmental biases was operationally defined as the magnitude of the accuracy cost in low vs. high probability conditions, with those who were more influenced by the task-irrelevant factor of item probability deemed as those with a larger bias. Individuals who were more susceptible to the probability bias were more influenced by trial-to-trial information in the main visual search task. Specifically, higher probability biases related to (1) lower accuracy during low prevalence searches, (2) higher false alarm rates following an incorrect target miss as compared to a correct target hit, and (3) slower and less accurate target identification following a target present trial than a target absent trial. Importantly, the magnitude of the probability bias did not relate to overall accuracy or target sensitivity, suggesting that the effects were specific to trial-to-trial influences. Collectively, these results suggest individual differences in susceptibility to environmental biases relate to a multitude of search performance metrics and highlight that certain individuals may not be best suited to conduct high-stakes searches (e.g., radiology, airport security).

Acknowledgement: Army Research Office

52.12, *11:00 am* **Short-term and long-term attentional biases to frequently encountered target features**

Sha Li[1](lixx3632@umn.edu), Roger Remington[2,3], Yuhong Jiang[1,3]; [1]Department of Psychology, University of Minnesota, [2]School of Psychology, University of Queensland, [3]Center for Cognitive Sciences, University of Minnesota

It has long been known that frequently occurring targets are better attended than infrequent ones in visual search. But does this frequency-based attentional prioritization reflect short-term inter-trial priming or durable statistical learning? Here we show that both short-term and long-term mechanisms contribute to attentional biases for visual features. However, they are supported by different types of statistical associations between targets and features. Four experiments showed that a manipulation of the target's probability of having specific features induced only short-term prioritization of the more probable feature. In contrast, a manipulation of a feature's probability of being associated with a target rather than distractors (the feature's diagnostic value) produced a durable attentional bias towards the more diagnostic feature. Participants searched for a target, a line oriented horizontally or vertically among diagonal distractors, and reported its length. In one set of experiments we manipulated the target's color probability: targets were more often in Color1 than Color2. Distractors were in other colors. Participants found Color1 targets more quickly than Color2 targets, but this preference disappeared immediately when the target's color became random in the subsequent testing phase. In another set of experiments we manipulated the diagnostic values of two colors. Color1 more often coincided with targets than distractors; Color2 more often coincided with distractors than targets. Participants found Color1 targets more quickly than Color2 targets. Importantly and in contrast to the first set of experiments, the featural preference was sustained in the testing phase. These results show that short-term and long-term attentional biases are products of different statistical information. Finding a target momentarily activates its features, inducing short-term repetition priming. Long-term changes in attention, on the other hand, rely on learning diagnostic features of targets.

52.13, *11:15 am* **More than a memory: Confirmatory visual search does not occur when target colors are merely remembered**

Jason Rajsic[1](jason.rajsic@mail.utoronto.ca), Jay Pratt[1]; [1]Department of Psychology, University of Toronto

During visual search for two mutually exclusive targets, attention is biased towards whichever of the targets the search is framed as "for". For example, when looking for a P that can be either green or red, if participants have to answer the question "is the P red?", they will tend to search through red items. Green items, by comparison, are neglected, even though they provide information; on the half of trials the P is green, and therefore not red. Does this confirmation bias occur simply because one target's color is held in working memory? In the present study, two groups of participants completed visual searches for one of two possible colored targets letters in displays of stimuli drawn in two colors. One group was asked to search for the target letter while maintaining a particular color in memory, and after each search their memory was tested to confirm that the color was remembered. A second group was instead asked whether the target letter was a particular color, with no additional memory load. By varying the ratio of the number of stimuli drawn in these two colors, we tracked which subset was being prioritized. Search frames (is the p red?) produced a robust bias towards the subset matching one target type. However, requiring participants to remember a color (e.g., red) did not produce biases towards subsets matching the color held in memory, despite showing a recognition advantage for targets matching the color held in memory. These data show that visual confirmation bias is not merely a result of the contents of working memory. More broadly, these results support the notion that there is more to guiding visual attention to stimulus features than simply holding features in memory.

Acknowledgement: NSERC PDF to Jason Rajsic

52.14, *11:30 am* **Visual search in large-scale spaces: Spatial memory and head movements**

Chia-Ling Li[1](sariel.cl.li@utexas.edu), M. Aivar[2], Matthew Tong[3], Mary Hayhoe[3]; [1]The Institute for Neuroscience, The University of Texas at Austin, [2]Facultad de Psicología, Universidad Autónoma de Madrid, [3]Center for Perceptual Systems, The University of Texas at Austin

In everyday search, both visual information and spatial memory are used, even when targets are within the field of view. Yet little is known about the relative importance of these two kinds of cue and how they work together. It seems likely that spatial memory representations guide not only eye movements but also head and body movements (Aivar et al., 2015; Won et al., 2015). We explored this issue in a large-scale immersive environment. Subjects searched for targets located on four surfaces in each of the two rooms in a virtual reality apartment. At the start of each trial, the target was presented on a TV at the end of the hallway separating two rooms. Subjects turned around to make either a left or right turn to enter a room. To test if memory aided search by guiding head movements once they entered the room, we analyzed the angles between head and target direction while making the first fixation to the target. The results showed that the angles from the head to target became about 24 degrees smaller after only three repetitions of search (at least for the target located at locations that are easiest to orient to upon entrance). The next question is whether memory could help prepare the body to move in the right direction even before entering the room. The angles between head and target direction one second before entering the room were analyzed. Smaller angles were found with experience (about 11 degrees), even though targets were not visible. Together, the findings suggested that spatial memory for the target location is used for advanced planning of body movements, even before the search scene is visible. Thus making movement decisions based on memory allows for more efficient search when body movements are involved.

52.15, *11:45 am* **Detecting the "gist" of breast cancer in mammograms three years before the cancer appears.**

Hayden Schill[1](hayden.schill@gmail.com), Anne-Marie Culpan[2], Jeremy Wolfe[1,3], Karla Evans[4]; [1]Brigham & Women's Hospital, [2]University of Leeds, [3]Harvard Medical School, [4]University of York

Tuesday AM

Studies have shown that radiologists can distinguish normal from abnormal mammograms at above chance levels after viewing the images for 500 msec even when the signs of cancer are quite subtle. The radiologists are at chance when they attempt to localize the lesion, suggesting that a global/texture signal underpins the detection of these subtle abnormalities (Evans et al, 2013). This ability persists even when radiologists only view the breast contralateral to the cancer indicating that the signal is not based on the presence of the lesion in the image (Evans et al, 2016). Is that signal present as a warning sign before the cancer, itself, appears? We presented 21 radiologists with bilateral mammograms that had been acquired 3 years prior to the mammograms that showed visibly actionable cancer intermixed with completely normal mammograms. Thus, the abnormal cases were "normal" mammograms of patients who would later develop breast cancer. Participants were asked to rate the likelihood of abnormality of the images on a 0-100 scale. Exposure duration was 500 msec. Rating scale data were converted to ROC curves and d' was calculated. The ability to distinguish normal from abnormal (cancer priors) was small (d'=0.2) but statistically significant (p< 0.001). Even though radiologists were viewing images taken 3 years prior to any visible signs of cancer being detected, they were able to classify images as normal or abnormal at above chance levels. The result was not due to a few salient cases nor was it correlated with breast density (a known risk factor). This supports the hypothesis that radiologists have access to a global, non-selective signal of abnormality. If that signal could be reliably detected by humans or by computational systems, it could be a valuable part of the effort to assess an individual woman's risk factors and detect cancer early.

Acknowledgement: NIH - 1R01CA207490-01

52.16, *12:00 pm* **Cortical evidence for negative search templates** Reshanne Reeder[1](reshanne.reeder@ovgu.de), Christian Olivers[2], Stefan Pollmann[1, 3]; [1]Department of Experimental Psychology, Institute of Psychology II, Otto-von-Guericke University, Magdeburg, Germany , [2]Department of Experimental and Applied Psychology, Vrije Universiteit, Amsterdam, Netherlands , [3]Center for Behavioral Brain Sciences, Magdeburg, Germany

Predefined targets of visual search are thought to be actively represented in a "target template", but little is known about the representation of impending distractors. Knowing what to ignore prior to search should improve distractor inhibition and benefit target detection; thus it would be beneficial to set up a "negative template" specifying distractor features. The question is whether preparing for targets or preparing for distractors involve different preparatory representations. Is a negative template the same as a target template? Is it something completely different? Or does it simply not exist (i.e. distractor information is simply ignored)? In the current study, we compared the representations of different types of information prior to search, using fMRI. Specifically, we compared prior distractor information to prior target information, or task-irrelevant information. Subjects were required to search for a letter T among slightly different distractors enclosed in differently colored circles. Prior to search, a color cue appeared with one of three symbols: "+" (positive cue: the target will appear in the same color); "—" (negative cue: only distractors will appear in the same color); or "o" (neutral cue: this color will not appear in the search display). fMRI results showed increased activation in large parts of visual cortex following the positive cue compared to the negative cue. The negative cue showed deactivation as compared to the neutral cue in largely the same regions. The neutral cue, compared to the task-relevant cues, showed increased BOLD signal in superior parietal lobule bordering precuneus, a region previously found to be involved in actively ignoring irrelevant spatial stimuli. These results reveal that negative templates have a distinct neurophysiological signature compared to either target templates or completely irrelevant stimuli.

Acknowledgement: DFG grant PO 548/16

52.17, *12:15 pm* **A suppression template for multiple distractors in visual search** Bo-Yeong Won[1](bywon@ucdavis.edu), Joy Geng[1]; [1]Center for Mind and Brain, University of California, Davis

To search efficiently, it's ideal to pursue a goal-relevant object (i.e., target) without any distraction from goal-irrelevant objects (i.e., distractors). In reality, however, it's almost always necessary to filter out distractors. Previous research showed people create a distractor template for rejecting specific distractors (Arita et al., 2012). However, it's still unclear if the distractor template can be made for multiple distractors simultaneously. Doing so would be advantageous for complex environments in which distractors outnumber targets. We investigated this question using a visual search task in which participants searched for a gray (target) square among colored distractors (see supplemental figures). During "training", participants saw the same three colored distractors either simultaneously (Experiment 1,2,4) or sequentially (Experiment 3). During "testing", two new distractors sets were interleaved with the trained distractors. The critical manipulation in each study was based on the distance (in color space) of the new "test" distractors from the learned "trained" distractors. We hypothesized that if the trained distractor template created is inclusive enough to suppress the new "test" distractors, then search performance should be just as good with the new distractors as the old ones. In contrast, if the template is specific to the trained colors, then performance should be worse. Experiment 1 found no performance cost for new distractors near the outer range of trained distractors, but significant cost for distractors farther away. Experiment 2-3 found that new distractors within the trained color range also showed no performance cost, and replicated the finding that distractors farther outside of trained color range interfered with performance. Finally, in Experiment 4 we found that the distractor template was not narrowly defined by the mean of three trained colors. This study suggests that multiple distractors create a broad template that suppress all feature values within (and very near) the trained color range.

MOTION: NEURAL MECHANISMS AND MODELS

Tuesday, May 23, 10:45 am - 12:30 pm
Talk Session, Talk Room 2
Moderator: Tatiana Pasternak

52.21, *10:45 am* **Inactivation of lateral prefrontal cortex increases activity of MT neurons during memory-guided comparisons of visual motion** David Samu[1](david.samu@upf.edu), Ruben Moreno-Bote[1], Albert Compte[2], Tatiana Pasternak[3]; [1]Department of Information and Communication Technologies, University Pompeu Fabra, [2]Institut d'Investigacions Biomediques August Pi i Sunyer, [3]Department of Neuroscience, University of Rochester

It is widely accepted that lateral prefrontal cortex (LPFC) is a likely source of top-down influences on neurons processing sensory information. Although the details of top-down connectivity from the LPFC to motion processing area MT remain to be worked out, the existing anatomy suggests that the direct inputs to MT originate in the more ventral prearcuate region of the LPFC (8Av), while the dorsal portion (8Ad, 46) sends direct inputs to the parietal cortex (Petrides & Pandya, 2006). Despite the difference in their targets, the two sub-regions show similarities in the behavior of their neurons during memory-guided motion comparisons, displaying direction selective activity indicative of the bottom-up signals arising in MT (Zaksas & Pasternak, 2006). We examined the functional parcellation of the top-down influences of the LPFC by recording activity in MT before and after inactivating sub-regions within the LPFC, while monkeys compared directions of two moving random-dot stimuli, separated by a delay. Inactivation of the dorsal sub-region resulted in dramatic increases in the firing rates of the majority of recorded neurons throughout the entire trial, but no measurable effects on behavioral performance, largely intact tuning for motion direction and preserved anticipatory modulation of delay activity. In response to motion, the upward shift in mean activity was accompanied by a proportional increase in variance, suggesting additive increase in gain indicative of a shift in the operational regime of neuronal circuits within MT. This non-specific disinhibition involving the majority of MT neurons following LPFC inactivation is consistent with the operation of the Inhibitory Stabilizing Network model which provides a powerful account for the balance between excitation and inhibition in cortical networks (Rubin et al, 2015). Ongoing inactivation involving the ventral portions (8Av) of LPFC will reveal whether different sub-regions within the LPFC give rise to different types of top-down influences.

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Tuesday AM

52.22, *11:00 am* Opponency in the middle temporal complex: Counter-phase dot motion is processed like non-motion Andrew Silva[1](aesilva@ucla.edu), Benjamin Thompson[2], Zili Liu[1]; [1]University of California, Los Angeles, [2]University of Waterloo

During the opponency stage of computational motion-processing models, the responses of two directionally-selective cells with opposing preferred directions are subtracted (Adelson & Bergen, 1985). This calculation outputs the local direction of motion and reduces further processing of non-informative flicker-noise. A biological implementation of opponency involving brain area MT is speculated to exist, since MT neurons are poorly driven by counter-phase motion stimuli. Counter-phase stimuli are created by spatially pairing oppositely-moving dots such that any local area contains balanced quantities of opposing signals (Qian & Andersen, 1994). If the weak MT response to counter-phase motion is truly indicative of a noise-reducing mechanism, then this response may resemble MT's response to flickery non-motion stimuli. Furthermore, when included as background distractors in a direction discrimination task, task-irrelevant counter-phase and non-motion stimuli may similarly affect behavioral performance. In the current project, we examined these predictions using psychophysics and fMRI. We created a non-suppressed in-phase stimulus to use as a control comparison by reversing the direction of one dot in each counter-phase pair. During the psychophysical experiment, participants judged whether target dots moved coherently leftward or rightward. This task was embedded within counter-phase, in-phase, and non-motion backgrounds. During the fMRI experiment, counter-phase, in-phase, and non-motion stimuli were presented without target dots to collect clean patterns of activation. As predicted, in-phase trials elicited high BOLD responses and high behavioral thresholds, while counter-phase and non-motion trials elicited similarly low BOLD responses and behavioral thresholds. Moreover, a three-way MVPA classification of MT fMRI data found good classification of in-phase stimuli, but poor discrimination between counter-phase and non-motion stimuli. All together, these results suggest that counter-phase and non-motion stimuli are processed similarly, strengthening the idea that the weak MT response to counter-phase motion is a signature of the brain's noise-reduction mechanism.

Acknowledgement: This material is based upon work supported by the National Science Foundation Graduate Research Fellowship under Grant No. DGE-1144087

52.23, *11:15 am* Spatial arrangement of multiple moving stimuli with competing features alters normalization of neuronal responses Steven Wiesner[1,2,3](swiesner@wisc.edu), Xin Huang[1,2,3]; [1]Department of Neuroscience, University of Wisconsin-Madison, [2]Physiology Graduate Training Program, [3]McPherson Eye Research Institute

Objects in the natural world usually have multiple features that each can vary in strength. We previously showed that neuronal responses in extrastriate area MT elicited by two overlapping, moving stimuli can be described as a weighted sum of the neuronal responses, and the weight is stronger for the stimulus that has a stronger signal strength. These results can be explained by response normalization. Here we investigate how MT neurons of fixating monkeys respond to multiple moving stimuli that have two competing features, motion coherence and luminance contrast. Visual stimuli were two random-dot patches moving simultaneously in different directions separated by 90°. The diameter of each patch was 3°. One patch moved at a high coherence (100%) with a low contrast (36%) (Hcoh/Lctr), whereas the other moved at a low coherence (60%) with a high contrast (77%) (Lcoh/Hctr). The two patches were placed within the receptive fields (RFs) of MT neurons, and either overlapped, or were separated with at least 1° gap in-between. We varied the vector-averaged direction of the two patches to characterize the direction tuning. We found that although the MT response elicited by Hcoh/Lctr patch alone was significantly stronger than that elicited by Lcoh/Hctr patch, MT response elicited by two patches was strongly biased to the weaker Lcoh/Hctr patch response when the two patches overlapped. When the two patches were separated, MT response showed a drastic change and became slightly biased to the stronger HCoh/Lctr patch response. When overlapping, the two patches compete within the RFs of both V1 and MT neurons, whereas when separated, the two patches compete within the RFs of only MT, but not V1 neurons. Our results highlight the importance of normalization occurring at different stages of visual processing that differ in spatial scale and preference for stimulus feature in shaping neuronal responses.

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52.24, *11:30 am* When invisible noise obscures the signal: the consequences of nonlinearity in motion detection Jenny Read[1](jenny.read@ncl.ac.uk), Ghaith Tarawneh[1], Vivek Nityananda[1], Ronny Rosner[1], Steven Errington[1], William Herbert[1], Bruce Cumming[2], Ignacio Serrano-Pedraza[3]; [1]Institute of Neuroscience, Newcastle University, [2]National Eye Institute, National Institutes of Health, [3]Department of Psychology, Universidad Complutense de Madrid

Many models of neural processing consist of series of linear-nonlinear cascades, where at each stage inputs are pooled linearly and then undergo a nonlinearity such as squaring. One example is the motion energy model, the standard model of motion detection in animals from beetles to humans. Despite the energy model's nonlinearity, linear system analysis continues to be successfully applied in motion perception, as well as in other domains of visual neuroscience such as contrast and disparity. A critical assumption of many linear systems approaches is that noise injected at a frequency to which a sensory system does not respond has no effect on the system's ability to detect a signal. Even simple nonlinearities, as used in the energy model, mean that this assumption does not necessarily hold. We show that when early spatial filtering is lowpass, as in insect vision, the nonlinear nature of the energy model predicts that motion detection will be impaired by "invisible"' noise, i.e. noise at a frequency that elicits no response from the animal when presented on its own as a signal. We confirm this surprising prediction using the optomotor response of the praying mantis Sphodromantis lineola. Conversely when early filtering is spatially bandpass, as in mammalian vision, the effect does not occur and invisible noise has no effect. This means that masking techniques, which examine what frequencies of noise impair the detection of a signal, are able to reveal the sensitivity of motion channels in mammals but not insects. Thus, although the computations extracting motion have the same structure in both insects and mammals, differences in the early stages of visual processing produces radically different responses to noise. Counter-intuitive effects such as masking by invisible noise may occur in neural circuits wherever a nonlinearity is followed by a difference operation.

Acknowledgement: The Leverhulme Trust

52.25, *11:45 am* Neural responses to motion in 2 and 3 dimensions Peter Kohler[1](pjkohler@stanford.edu), Wesley Meredith[1], Anthony Norcia[1]; [1]Department of Psychology, Stanford University

Past research has suggested that lateral motion and motion in depth are supported by different mechanisms. Here we present a series of steady-state VEP measurements, comparing responses to absolute and relative 2D and 3D motion in random dot displays, under conditions of vertical and horizontal binocular disparity. Displays consisted of test bars undergoing coherent lateral motion (2 Hz) that was either in phase between the two eyes or in anti-phase, alternating with reference bars without coherent motion. When motion was in anti-phase and bars were horizontal, the display produced horizontal binocular disparity consistent with 3D motion-in-depth. When the display was rotated 90º, the vertical bars produced vertical disparity, which is not perceived as motion-in-depth. In-phase motion was perceived as 2D in-plane motion. Reference bars either contained static dots, producing relative motion/relative disparity between the test and reference bars, or incoherent motion, in which case only the absolute motion/absolute disparity modulation of the test bars remained. We measured motion-response functions by sweeping dot displacements from 0.5 to 16 arcmin. At the even harmonics, which reflect steady-state responses that are equivalent regardless of motion direction (left/right, up/down, towards/away), we saw a clear difference between 2D and 3D relative motion, where response thresholds were lower for 2D than 3D. This difference persisted for both the horizontal and vertical bars, suggesting that stereo-movement suppression (Tyler, 1971) may not solely be the result of perceived motion in depth. Absolute 3D motion produced weaker, but detectable responses for both display orientations, while responses to absolute 2D motion did not. A follow-up experiment using a blank reference bar for the absolute motion conditions replicated the previous results, except that absolute 2D

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motion now produced measurable responses. This result suggests that the motion system pools coherent and incoherent motion over space with a resulting reduction in sensitivity.

Acknowledgement: R01 EY018875 from the National Institute of Health

52.26, *12:00 pm* **Predicting human performance in a natural task with strongly constrained models of noise** Benjamin Chin[1](bechin@sas.upenn.edu), Johannes Burge[1]; [1]University of Pennsylvania

Visual processing in any natural task is limited by at least three sources of uncertainty: natural stimulus variability, early noise, and late noise. Natural stimulus variability is due to the task-relevant statistical structure of natural scenes, and is irreducible. Early (input) noise is due to factors prior to nonlinearities in the visual system (e.g. photon noise), and is also irreducible. These sources of uncertainty are 'external noise'. 'Internal' (or late) noise is due factors after nonlinearities in visual processing. Here, in three human observers, we use a suite of tools to predict the impact of each source of uncertainty on visual processing in the task of speed estimation from natural image movies. First, we measured the early noise in a target detection task using the equivalent input noise paradigm. Second, using an ideal observer for speed estimation in natural image movies, we determined the combined impact of natural stimulus variability and early noise on performance in a speed estimation experiment; every presented movie was unique. Third, we measured human performance with matched natural stimuli, and compared human and ideal performance. The ideal observer accounts for ~95% of the variance in the human responses across all conditions with a single free parameter (efficiency). Fourth, each human observer repeated the experiment with the exact same set of movies (double pass paradigm), and we determined the proportion of times that responses agreed. Response agreement is determined by the ratio of internal to external noise. Under the hypothesis that human inefficiency is due only to internal late noise, efficiency should tightly predict response agreement (zero additional free parameters) in the double pass experiment; maximum likelihood fits strongly confirm the prediction. Thus, an analysis of task-relevant natural stimulus variability, and strongly constrained noise models fully account for human performance in a speed estimation task.

52.27, *12:15 pm* **CAN SPEED BE JUDGED INDEPENDENT OF DIRECTION?** Oliver Braddick[1](oliver.braddick@psy.ox.ac.uk), Rory Trevelyan-Thomas[1], Catherine Manning[1]; [1]Department of Experimental Psychology, University of Oxford

The ability to judge speed is a fundamental aspect of visual motion processing. Speed judgments are generally assumed to depend on signals in motion-sensitive, directionally selective, neurons in areas such as V1 and MT. Speed comparisons might therefore be expected to be most accurate when they use information within a common set of directionally tuned neurons. However, there does not appear to be any published evidence on how well speeds can be compared for movements in different directions. We tested speed discrimination judgments between pairs of random-dot stimuli presented side-by-side. 12 participants judged which appeared faster of a reference stimulus moving vertically upwards or downwards at 6 deg/sec, and a comparison stimulus moving either in the same direction or in a direction differing by 180º, ±45º or ±90º. The point of subjective equality (bias) and sensitivity (slope of the psychometric function) were estimated from individual psychometric functions fitted for each condition. We found no systematic differences in sensitivity across different directional combinations. However, when the comparison stimulus moved orthogonally (±90º) to the reference stimulus, but not in other combinations, it was judged to move faster than the reference stimulus. We conclude that while there are directional biases in speed information, it can be equally efficiently compared whether it is derived across or within direction channels. These results inform our understanding of how information is extracted from the joint representation of speed and direction, and guide methods for testing motion processing in typical and atypical development.

Acknowledgement: CM: Scott Family Fellowship in Autism and Related Disorders

Attention: Capture

Tuesday, May 23, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

53.3001 A Visual Imagery Induced Reversal of Priming of Pop-out

Brett Cochrane[1](cochraba@mcmaster.ca), Andrea Nwabuike[1], Dave Thomson[2], Bruce Milliken[1]; [1]Department of Psychology, Neuroscience, & Behaviour, McMaster University, [2]Department of Psychology, University of Toronto

Maljkovic and Nakayama (1994) found that pop-out search performance is more efficient when a singleton target feature repeats rather than switches from one trial to the next – an effect known as Priming of PoP-out (PoP). They also reported findings indicating that the PoP effect is strongly automatic, as it was unaffected by knowledge of the upcoming target color. Across several experiments, we explored the impact of top-down strategies on the magnitude of the PoP effect by instructing participants either to imagine or to verbalize a color between trials of a pop-out search task. Under these conditions, responses were faster for targets that matched an imagined color than for targets that matched the previous target color, reversing the typical PoP effect. There was no such reversal of the PoP effect for those in the verbalize group. Further, we explored whether visual imagery and the PoP effect impact the same or different processes by comparing conditions in which a PoP effect either could or could not modulate the influence of visual imagery. We found that self-reported strong visual imagery eliminated the influence of PoP on visual imagery mediated search performance, suggesting that visual imagery impacts the same processes as drive the PoP effect. Overall, the results suggest that the processes driving the PoP effect are sensitive to top-down strategies that involve visual representations.

Acknowledgement: National Science and Engineering Research Council of Canada Discovery Grant

53.3002 Attentional Dwelling and Capture by Color Singletons

Eric Ruthruff[1](ruthruff@unm.edu), Michael Faulks[1], Joshua Maxwell[1], Nicholas Gaspelin[2]; [1]Department of Psychology, University of New Mexico, [2]Center for Mind and Brain, University of California, Davis

Can salient stimuli capture spatial attention against our will? To answer this question, many researchers have used the spatial cuing paradigm, in which a salient stimulus (the pcue) is presented shortly before a search display. Degree of capture by the cue is indexed by the cue validity effect: capture should speed up responses when the cue and target are in the same location, but slow responses when they are in different locations. Gaspelin, Ruthruff, and Lien (in press), however, recently questioned this logic. They reported that the same abrupt onset cue can produce either small or large cue validity effects, depending on search difficulty. Cue validity effects, it seems, depend not only on the probability of capture, but also the cost of capture incurred during search (attentional dwelling). The present experiments extended this approach to the study of color singletons. Participants searched for a perfect circle among either heterogeneous ovals (requiring feature search) or homogeneous ovals (enabling singleton search). Feature search yielded little or no cue validity effect, even from highly salient color singletons. Singleton search, however, yielded cue validity effects that increased linearly with search difficulty, ranging from nearly 0 ms with easy search to roughly 100 ms with difficult search. Importantly, difficulty conditions were randomly intermixed, so participants could not adjust their attentional set in anticipation of difficulty level. We conclude that whereas onsets can capture attention based purely on salience, color singletons capture attention only when partially task relevant. Furthermore, we confirmed that search difficulty is a critical determinant of cue validity effects. To ensure sensitivity to attention capture, spatial cuing experiments should employ a difficult search.

53.3003 Surprising depth cue captures attention in visual search

Thorsten Plewan[1](plewan@ifado.de), Gerhard Rinkenauer[1]; [1]Leibniz Research Centre for Working Environment and Human Factors

There is a substantial amount of evidence indicating that surprising events capture attention. A prototypical experimental paradigm comprises a target which has to be identified within a circular array of distractors. Initially, all possible locations are cued by uninformative placeholders. After a predefined proportion of trials one cue will unexpectedly be presented in a deviating color. It has been shown that such surprising events can immediately capture attention and facilitate task performance. Similar effects have been observed if the target itself was surprisingly colored or accompanied by a motion cue. In contrast, presenting surprising information on a distractor location elicits more errors and longer processing time. The present study was intended to investigate whether unexpected depth cues are also able to immediately capture attention and whether cues in near or far distance differentially modulate behavior. For this purpose, the outlined experimental design was adopted and presented via stereoscopic head-mounted displays. This way a pronounced depth impression could be induced which offered the possibility to display the critical cue in a closer or more distant depth position than the target. In line with previous results both depth cues did capture attention on their first appearance. The accuracy in the critical trial (i.e. first appearance of the depth cue) was superior to the error rates in the trials without cue and was also better than error rates in the remaining trials with cue. Moreover, response times were faster in trials with depth cue and this was already true for the critical trial. No other marked differences between near and far depth cues were observed. The results emphasize that surprising depth information captures attention and thus can influence perceptual processes. However, in contrast to other experimental paradigms, the relative position in depth (near vs. far) does not considerably affect search performance.

Acknowledgement: Deutsche Forschungsgemeinschaft (Research Training Group 1855)

53.3004 Examining the influence of different types of dynamic changes to targets and distractors in a visual search task

Mengzhu Fu[1](mengzhu.fu@huskers.unl.edu), Joshua Zosky[1], Michael Dodd[1]; [1]Department of Psychology, University of Nebraska - Lincoln

Previous studies have demonstrated that search performance for objects is greatly impaired when the targets and distractors are dynamic relative to static. Recently, Jardine and Moore (2016) examined this effect via dynamic motion wherein items in the display rotated in place continuously. It remains unclear, however, whether the observed impairment is specific to motion or whether other dynamic changes exert a similar effect. In the present study, we replicate the original Jardine and Moore finding and extend this examination to consider other dimensions, including increasing object complexity (schematic faces with continually changing expressions vs. similar object changes independent of a face context) and utilizing color-changed objects. Targets and distractors are presented at fixed locations and participants are required to search for an oddball target (e.g. a face with a smiling or frowning mouth relative to neutral expressions or a color patch that differs relative to a series of uniform distractors) during a critical frame, indicated by a border cue.. The results suggest that some, but not all, types of dynamic change impact performance. Specifically, oddball color targets and oddball orientation targets continue to pop out even when the items in the display are dynamic, but this is not the case for the more complex faces, which participants are poor at detecting. These findings demonstrate that the influence of dynamic context on search performance is not absolute, and is instead strongly influenced by the nature of the change to the display.

53.3005 The development of chasing detection: Do 4-year-olds show evidence of a pop-out effect for chasing stimuli?

Ruth Hofrichter[1](hofricrm@mcmaster.ca), M. Rutherford[1]; [1]McMaster University (Department of Psychology, Neuroscience & Behaviour)

Introduction. Humans attend selectively to animate stimuli (New, Cosmides & Tooby,2007) and interpret biological motion as goal-directed (Heider & Simmel, 1944; Tremoulet & Feldman, 2000). Meyerhoff, Schwan & Huff (2014) reported evidence of a pop-out effect for chasing displays: a chasing pair of circles was shown among a varying number of distracters, and reaction times for identifying the chaser did not increase proportionately to the number of distracters. Both animacy perception and chasing detection develop early in life (Rochat, Striano & Morgan, 2004; Frankenhuis, House, Barrett & Johnson, 2013). The purpose of this study was to test whether attention to chasing, as evidenced by the pop-out effect, has developed by the age of 4. Method. Participants were adults and 4-year-olds. We adapted Meyerhoff et al.'s (2014) procedure for use with 4-year-olds, by using a decorated touch screen to display stimuli and record responses and adding a child-engaging cover story. The stimuli set consisted of black circles presented on a green background. The chaser, chasee and distracters were identical in appearance. On each trial, the chasing pair was presented among a varying number of distracters (2,4,6,8,10). The chasee and distracters moved around the screen in a randomly determined pattern while the chaser pursued the chasee in a heat-seeking fashion. Participants were tasked with identifying the chaser by touching it on the screen. Results and Discussion. We hypothesized that we would find a pop-out effect for chasing stimuli among non-chasing distracters for both adults and 4-year-olds. Our independent variable was number of distracters and our dependent variable was reaction time. The number of distracters did not predict reaction time for adults ($F(1, 136) = 0.026$, $p< .05$) or 4-year- olds ($F(1, 49) = 1.892$, $p< .05$), which is consistent with a pop-out effect for chase stimuli.

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53.3006 Salient distractors speed responses when targets are absent in visual search

Jeff Moher[1](jeff.moher@williams.edu); [1]Psychology Department, Williams College

Perceptually salient distractors frequently capture attention. In most research on this phenomenon, attention capture is measured by asking participants to identify a target on each trial, and comparing performance as a function of whether a salient distractor was present or not. However, in many real world search tasks such as medical image screening, targets are often absent. I examined the impact of salient distractors on search trials in which participants had to press a key to indicate whether or not a target was present. Three factors were varied randomly and orthogonally across trials: set size (4 vs. 8), salient distractor (present vs. absent), and target (present vs. absent). As expected, on target present trials, response times (RTs) were longer when a salient distractor was present than when it was absent. However, on target absent trials, RTs were shorter when a salient distractor was present. One possible explanation is that salient distractors may reduce quitting thresholds; that is, participants are more likely to assume that no target is present when a salient distractor is present. Consistent with this view, miss rates on target present trials were higher when salient distractors were present. This effect was robust across multiple experiments, as salient distractors produced shorter RTs on target absent trials when targets were rare (Experiment 2), and when accuracy feedback was provided after each trial (Experiment 3). Ongoing eye-tracking experiments will shed further light on the mechanism by which these distractor-induced speeded RTs occur. Together, these data shed new light on the mechanisms by which salient distractors impact performance. These results have important implications not only for models of attention, but also for real world search tasks in which targets may be absent, and distractions may occur.

53.3007 Attention and Suppression: Awareness-Independent Same-Location Costs in Relational and Feature Search for Spatial Frequency Targets

Ulrich Ansorge[1](ulrich.ansorge@univie.ac.at), Tobias Schoeberl[1]; [1]Faculty of Psychology, University of Vienna, Austria

Visual cues capture attention when they match to the top-down search settings of the observer: Singleton cues that share a searched-for feature with a target facilitate searching for the target stimuli when they appear in the same display location as the target (valid condition) compared to when they appear in a different location (invalid condition). In contrast, when a singleton cue does not match to the top-down search settings, search can be impaired in valid compared to invalid conditions. This reversed pattern, the same-location cost (SLC), has been suggested to originate from an awareness-dependent updating of object files in working memory: Only in valid and non-matching conditions the feature of a relevant location-defined target-object file would change across time (from cue to target). But SLCs could also reflect suppression of capture. We therefore tested the object-file updating hypothesis and its dependence on awareness: We established an SLC that was independent of the participant's awareness of the cue's location (as tested in a visibility test). We further showed that the SLC was not influenced by the extent of similarity between cue/cue display distractors and target and persisted when search was relational and a non-matching cue had the exact same features as the target at the same position. In contrast, data suggested an attentional origin of the SLC as it was positively correlated with cueing effects in top-down matching conditions.

53.3008 Distractor suppression in visual search: Converging evidence from electrophysiology and computational modelling

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The order of attention allocations in visual search is often explained by the operation of a pre-attentive priority map. If the search target is salient, thus achieving a high weight on that map, it typically summons attention immediately (efficient search). However, if a task-irrelevant item receives an even higher weight, attention is captured by this 'distractor' before it can be reallocated to the target. Although attentional capture is a widely examined phenomenon, it is still unclear what processes are required for continuing search following a misallocation of attention: does attention simply move on to the next item, or must the attended distractor be actively suppressed on the priority map? To examine this, we devised a task in which attention was reliably allocated first to the distractor and only then to the search target, as evidenced by an electrophysiological marker of attention allocation (N2pc). Importantly, attention allocation to the distractor was reliably followed by an electrophysiological correlate of active suppression (PD). Given this, we asked whether this suppression works instantaneously, independently of the distractor weight on the priority map, or whether it takes time dependent on that weight. We contrasted these two possibilities in computational models that either did, or did not, include a parameter reflecting distractor-weight-dependent time requirements for distractor suppression. Only model variants that included such a parameter could successfully explain the observed RT data patterns. Together, these findings indicate that distractor suppression is necessary for continuing search after attention was captured and that the time required for this process depends on the distractor weight on the priority map. We propose that the same mechanisms are involved when attention is misallocated towards non-salient distractors during inefficient search and that persistent suppression might act as a transient memory of visited distractor locations.

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53.3009 Topological change captures attention as potent as abrupt onset

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It has been long reported that abrupt onset consistently captures attention. However, the question remains that exactly what specific property of the onset causes attention capture. The topological approach suggests a novel analysis of the nature of onset: as topologically invariant transformation neither creates nor destroys an object, an object onset is essentially a topological change. A counterintuitive prediction of this topological account is that a topological change (in, for instance, holes) should, like onset, also captures attention, and even with the same potency as onset. We investigated this prediction in 11 experiments using a modified Yantis and colleagues' onset paradigm. Three main conditions were compared. In the condition of topological change of forms (TC), topological changes were specifically manipulated by introducing or removing holes in two items, one from a placeholder display and the other at the corresponding location in the test display (for instance, H-like into O-like or P-like letters, arrow into triangle, solid disk into ring or disk containing two-holes, and others; or vise versa). In the condition of onset, an item appeared in a test display at a location corresponding to a previously blank position in a placeholder display, and otherwise the placeholder and test displays were the same as those in TC. And in the condition of non-onset, changes were made between two items

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at the same location, from a placeholder and a test display respectively, in various non-topological form properties, luminance, and color. Subjects were required to search whether there was an odd item in test displays, and RTs were measured. The results consistently supported the topological account: both topological change of forms and abrupt onset captured attention as revealed by the same level of facilitation in visual search functions, while they both significantly speeded performance compared to the non-onset changes in non-topological features.

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53.3010 Irrelevant angry facial expressions attract attention and action

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Perceptually salient distractors, such as bright and flashing digital billboards, often attract attention involuntarily and disrupt target search, such as looking for specific road signs. However, low-level feature salience is not the only factor that affects attentional capture, as emotionally salient targets also receive prioritized attention during visual search. Given that emotional stimuli bias competition for attentional resources, examining how emotional distractors are processed during target selection is of critical importance for understanding adaptive human behavior in complex social situations. Here, we investigated how task-irrelevant faces with positive and negative expressions bias attentional allocation and goal-directed action during target search. Participants localized a gender-defined target in an array of four faces either with a simple keypress (Experiment 1) or a reach movement (Experiment 2) while trying to ignore emotional oddball faces that appeared in half of all trials. There were two emotional oddball expressions, happy and angry, while all other faces were neutral. We demonstrated increased interference from angry than happy oddball faces, with angry but not happy oddball faces slowing target search times compared to the emotional oddball absent condition (Experiment 1). We also observed faster and greater hand deviation toward angry than happy oddball faces (Experiment 2). Finally, Experiment 3 examined whether attentional capture by irrelevant angry expressions requires visual awareness. Participants identified target letters flanked by distractor letters with a face presented above or below the letters. The distractor face was neutral, happy, or angry, and visual awareness was manipulated by continuous flash suppression (CFS). We found that angry distractors, whether visible or invisible, slowed target identification. Together, our results revealed that attentional capture is affected by an object's emotional content, regardless of task goals and awareness. Additionally, angry expressions are not only attention-grabbing, but also capable of biasing rapid action responses regardless of an observer's intentions.

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53.3011 Proportional Context of Distracters alters Top-Down Sets during Contingent Attention Capture

Dick Dubbelde[1](dubbelde@uwm.edu), Adam Greenberg[1]; [1]University of Wisconsin - Milwaukee

Top-down attentional sets instantiate a filter used to search for target feature(s) of interest in rich environmental contexts. Evidence suggests that top-down sets sometimes modify under certain conditions but the pressures causing these adjustments are poorly understood. Here, we examined whether context can drive top-down set plasticity by manipulating the proportion of key colored distracters in a contingent attention capture paradigm. We presented subjects three rapid serial visual presentation (RSVP) streams of colored letters, one central (target stream) and one to either side (two distracter streams), and asked them to identify a red letter within the, otherwise heterogeneous, target stream. The, otherwise homogenous, distracter streams contained four types of letters: neutral colored (gray), target colored, non-target colored (a color singleton), or threshold colored (determined via individual subject staircase tracking 75% difference threshold from target color). Our critical manipulation varied the proportion of four distracter types in the following three conditions: (1) equal occurrence of threshold (16.6%) and target (16.6%) colored distracters, (2) double occurrence of threshold (22%) versus target (11%) colored distracters, or (3) one-half occurrence of threshold (11%) versus target (22%) colored distracters. Neutral (50%) and non-target (16.6%) colored distracter proportions were fixed. If proportional context affects the plasticity of top-down sets, this will be reflected as a difference in threshold distracter accuracy between the two unequally proportioned conditions (conditions 2 & 3 above). Alternatively, if top-down sets are unaffected by proportional context, threshold distracter accuracy in these conditions should match that of the equally proportioned condition (condition 1). Results were consistent with the former prediction: threshold colored distracters captured attention differentially in conditions 2 versus 3. Thus, a simple change in the proportion of colored distracters led to a significant alteration of the top-down set, providing evidence that proportional context does, indeed, lead to top-down set plasticity.

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53.3012 Does Memory Consolidation Influence Memory-Driven Attentional Capture?

Kristina Krasich[1](kkrasich@nd.edu), Andrew Clement[1], Cary Stothart[1], James Brockmole[1]; [1]University of Notre Dame

To guide attention during visual search, observers must maintain a visual working memory (VWM) representation of the search target. Distractors often capture attention when they share features with this representation (or with other items in VWM). However, distractors are less likely to capture attention when they appear frequently across trials, suggesting that across multiple presentations items become consolidated in long-term memory (LTM) and deprioritized for attentional selection. Here, we assessed whether simply maintaining a VWM representation for an extended period of time, which allows for consolidation processes to stabilize the memory trace, would also reduce capture. Participants remembered a colored circle for 0s, .25s, .5s, 2.5s, 5s, or 10s, then searched for a target letter among colored distractors. They then reported the remembered item in a subsequent memory test. Notably, participants were slower to identify the target letter when a singleton distractor in the search display matched the color of the memory item. This effect occurred even at the longest time delays, suggesting that the time spent maintaining a single VWM representation does not change how attention is guided. In a second experiment, participants completed 30s of math problems prior to the search task, which served to disrupt VWM consolidation. Participants were slower to identify the target letter when a distractor matching the memory item was present, but only at longer time delays (>2.5s). This demonstrates that capture persists when there is sufficient time for VWM representations to be consolidated into LTM. In contrast to frequent presentation, findings suggest that increasing the time in which a VWM representation is maintained and consolidated into LTM does not reduce attentional capture.

53.3013 Interference from salient-but-irrelevant stimuli is influenced by emotional valence

Caroline Barras[1](caroline.barras@unige.ch), Coralie Pittet[1], Dirk Kerzel[1]; [1]University of Geneva

We investigated how interference from salient distractors is affect by their emotional content. We presented six shapes and participants searched for a flower with a missing petal. Participants had to indicate the side of this missing petal (left or right) by pressing one of two keys. Before the beginning of the experiment, participants were informed that one of two distractors would occasionally appear. A distractor was present on 66% of the trials. In 33% of trials, the distractor was a spider and in the other 33% of trials, it was a leaf. Results showed that interference from the distractor was larger with a spider compared to a leaf. Additionally, we measured event-related potentials. The target elicited an N2pc in the control condition. Interference from the spider and the leaf was accompanied by a contralateral positivity, the PD component. The PD was more positive with the spider compare to the leaf. Previously, the N2pc component was considered a measure of attentional capture whereas the distractor positivity (PD) was assumed to reflect attentional suppression. Our findings confirm that when the salient distractor is predictable, it can be suppressed. The spider was more strongly suppressed than the leaf suggesting that threatening singletons are avoided, in line with adaptive behavior. In sum, our results show that suppression of salient-but-irrelevant distractors is influence by their emotional valence.

53.3014 Automaticity and Specificity of Attentional Capture by Language Leeland Rogers[1](llrogers@psych.udel.edu), Sarah Fairchild[1], Anna Papafragou[1], Timothy Vickery[1]; [1]Department of Psychological and Brain Sciences, University of Delaware

The extent to which language affects non-linguistic processes is debated. While it is well-established that a spoken word quickly directs attention to the relevant object (e.g., Tanenhaus et al., 1995), recent research suggests that spoken language automatically guides visual attention even when it is task-irrelevant (Salverda & Altmann, 2011). Here, we ask whether stored linguistic knowledge – in the form of verbal labels associated with single objects – can capture attention when it is task-irrelevant. Participants were exposed to two novel manmade artifacts: one with a label associated (e.g., zeg) and one without. In a pilot study, after the training phase we administered a modified Posner cueing task (Posner & Petersen, 1989) in which locations were uninformatively precued with either labeled objects or unlabeled objects before having to respond to a target letter "F" appearing on the left or the right side of the screen. If stored linguistic knowledge associated with an object is capable of "capturing" attention to any extent, participants should be faster to respond to the target on trials where the labeled object is a valid cue for target location. Indeed, participants were faster on valid trials than invalid trials in the first block, $t(12) = 2.4$, $p < 0.05$, suggestive of attentional capture by labeled objects. We replicated this finding in a follow-up experiment that required localizing a non-linguistic target (a simple rectangle): participants were faster to respond on valid trials than invalid trials, $t(27) = 2.2$, $p < 0.05$. These findings provide evidence that stored linguistic knowledge is capable of capturing attention: merely learning a label to an object gives that object attentional priority.

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53.3015 Attentional control settings established via statistical learning are changed by context Sunghyun Kim[1](skim58@lsu.edu), Melissa Beck[2]; [1]Louisiana State University, [2]Louisiana State University

The present study explored whether multiple attentional control settings incidentally established are selectively, flexibly adapted depending on context. In the experiment, the modified contingent attentional capture paradigm was used. At the beginning of a trial, two placeholders were presented on either side of a central fixation. The shape of the central fixation and two placeholders was the same throughout a given trial, and was randomly changed between circle and square across trials. In the cue display, a red or green cue briefly (50ms) appeared at a randomly selected placeholder. In the search display shown immediately after the cue display, a search target defined by identity of a letter (Z and N) and a distractor letter (X, M, T, and V) were presented inside of the placeholders. Also, in the search display, the target letter and its placeholder were colored red or green, and the distractor letter and its placeholder were colored in the other. Crucially, in the training session, the color of the target letter and its placeholder were always red (green) when the shape of the fixation and placeholders were square (circle). But, this relationship was removed in the testing session, which was the only difference between the training and testing sessions. The results showed that during both the beginning of the testing session and the end of the training session, a red (green) cue, compared to a green (red) cue, captured attention more under the square (circle) context, suggesting that finely tuned (feature-based) attentional control settings established via statistical learning can be selectively, flexibly driven by context.

53.3016 Attentional control settings are stored in activated long term memory Lindsay Plater[1](lplater@uoguelph.ca), Maria Giammarco[1], Naseem Al-Aidroos[1]; [1]Psychology Department, University of Guelph

Recent work in our lab has shown that participants can adopt an attentional control set (ACS) for 30 visual objects, indicating that the contents of ACSs are stored in long term memory (LTM). This finding raises a question: What is unique about ACS representations in LTM that allows them to influence attentional capture, when most LTM representations do not? One proposition is that ACS representations are stored with greater than normal baseline activation, a state referred to as activated LTM (ALTM). In the present study we evaluated this proposition by testing whether ACS items exhibit a signature of ALTM: an intrusion effect in a working memory change detection task. Specifically, if ACS representations are maintained in ALTM, participants should be slow to correctly reject these items when they appear as the probe on "change" trials during this task. For our study, participants memorized 30 images of everyday visual objects and then completed two tasks, randomly mixed across trials: spatial blink trials (to induce an ACS for the memorized objects and to test for contingent capture), and visual working memory trials (to test for an intrusion effect). Replicating our previous contingent capture findings, on spatial blink trials, ACS objects captured attention more than non-ACS objects. On working memory trials, ACS objects produced an intrusion effect and non-ACS objects did not. This pattern supports the conclusion that the contents of ACSs are maintained in ALTM. More broadly, the present findings add to the growing evidence that LTM has rapid attentional effects during perceptual processing, and that these effects are regulated through differential activation of LTM representations.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

53.3017 Hemifield asymmetries in the additional singleton paradigm: Behavioral and electrophysiological findings Christophe Carlei[1](christophe.carlei@unige.ch), Caroline Barras[1], Nicolas Burra[1], Dirk Kerzel[1]; [1]University of Geneva

We measured behavioral and electrophysiological asymmetries in the additional singleton paradigm. Participants searched for a shape singleton and reported the orientation of a line segment inside. On some trials, one of the display elements (the distractor) had a color different from the others. At a behavioral level, the results showed that participants were faster to respond to targets in the lower than in the upper hemifield. Analysis of event-related potentials revealed that an index of attentional selectivity, the N2pc component, was also larger in the lower compared to the upper hemifield. This vertical asymmetry is in line with previous reports of enhanced visual acuity and stronger attentional capture in the lower hemifield when basic visual discrimination tasks were used. We also found that participants were faster to detect targets in the right compared to the left visual hemifield, which is consistent with the suggestion that "local" or high-resolution processing is improved in the right hemifield.

Attention: Divided

Tuesday, May 23, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

53.3018 Rapid adjustment of selective visual attention following errors Søren Andersen[1](skandersen@abdn.ac.uk), Marco Steinhauser[2]; [1]School of Psychology, University of Aberdeen, [2]Department of Psychology, Catholic University of Eichstätt-Ingolstadt

Selective attention focuses cortical processing resources on relevant information in order to allow for adaptive behavior despite the potential overload of sensory information. This process involves a fundamental tradeoff: a lower magnitude of attentional selectivity leads to impaired task performance due to interference from irrelevant information, but stronger attentional selectivity impairs the ability to detect and react to unexpected (and potentially dangerous) events. A possible explanation of how the magnitude of attentional selectivity is determined is offered by theories of performance monitoring, which assume that detecting errors leads to adaptive attentional adjustments that serve to prevent such errors in the future. However, although numerous studies have identified stages of error processing in error-related brain activity, it is still unclear how these stages are related to adaptive attentional adjustments. We investigated the time course of attentional adjustments elicited by errors. Participants attended to one of two superimposed red and blue random-dot kinematograms (RDKs) in order to discriminate the direction (horizontal vs. vertical) of brief motion intervals of the target RDK, while ignoring concurrent compatible or incompatible motions of the distractor RDK. The RDKs flickered at different frequencies, thereby eliciting distinguishable steady-state visual evoked potentials (SSVEPs), allowing us to concurrently measure the time-course of attentional allocation to both RDKs. Attentional selectivity of SSVEPs was increased almost synchronously with the error response and prior to conscious error detection. The magnitude of these attentional readjustments was large compared to the overall magnitude of attentional selectivity and linked to the earliest stage of error processing. Our findings suggest that error-induced attentional adjustments are a key determinant of the magnitude of attentional selectivity and start prior to conscious error detection.

53.3019 Improving vision with transcranial direct-current stimulation

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The transcranial Direct-Current Stimulation (tDCS) method would seem to lack the ability to selectively influence visual processing without affecting other cognitive abilities given its relatively poor temporal resolution and broad electrical fields. However, our recent research combining human electrophysiology with tDCS has shown that this type of noninvasive electrical brain stimulation can influence specific aspects of visual information processing without changing the operation of response selection, or other cognitive mechanisms beyond the fundamental mechanisms of the visual system. For example, when stimulating visual cortex, we find that we can change the earliest visual event-related potentials and fine-grained measures of visual acuity, but not subsequent electrophysiological indices of information processing. At the other end of the temporal continuum of visual processing, we can stimulate medial-frontal cortex and change the storage of representations in visual long-term memory, and thus how those objects are processed in the future, without changing other types of memory storage or late stage response selection. Thus, our findings indicate that tDCS is a surprisingly precise tool with which to study the visual system, offering additional possibilities of translating our discoveries into real-world treatments for vision problems.

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53.3020 Attentional capture by working memory does not interfere with visual feature perception

Emma Dowd[1](dowd.45@osu.edu), Samoni Nag[1], Julie Golomb[1]; [1]Department of Psychology, The Ohio State University

The active maintenance of visual items in working memory (WM) biases attention toward memory-matching objects. In dual-task paradigms that combine WM with visual search, the reappearance of the memory cue at a search distractor location results in slowed response times and misdirected first saccades (Soto et al., 2005), suggesting that spatial attention is captured by the memory-matching distractor. While WM-driven attention enhances early perceptual processing of subsequent targets at the memory-matching location (Pan et al., 2016), it remains unknown whether WM-captured attention enhances visual feature perception of distractor items, and if so, whether this might interfere with perception of the search target's features. For example, if spatial attention shifts to the memory-matching distractor before moving to the target, or is split between both locations, we might predict increased feature-binding errors (i.e., swap errors misreporting the distractor features or mixing errors blending the features; Golomb et al., 2014). Alternatively, attentional capture by the memory-matching distractor may be too transient or weak to disrupt perception of the target's features. Participants remembered a cue color across an intervening visual search, wherein they reported the orientation of a target grating, using a continuous-report procedure. Critically, search gratings were also colored. On half of the trials, the color of a distractor grating could match the memory cue. Probabilistic mixture models fit to orientation response distributions revealed decreased performance (higher proportion of uniform guessing) when a memory-matching distractor was present, consistent with WM-captured attention. However, we found no evidence of increased swap or mixing errors. Further experiments tested different combinations of visual features for memory and search stimuli and again found no increased swap or mixing errors. These data suggest that attentional capture by memory-matching distractors may slow or impair search performance, but does not interfere with perception of the target item's features.

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53.3021 Evidence of serial processing in visual word recognition

Alex White[1](alexlw@uw.edu), John Palmer[1], Geoffrey Boynton[1]; [1]Department of Psychology, University of Washington

Background: How much information can the human visual system process at once? This critical question is often studied by having observers make independent judgments of two simultaneous stimuli. Capacity limits impair accuracy in such a "dual-task" condition compared to a "single-task" condition, in which only one stimulus must be judged. The most extreme capacity limit manifests as serial processing: the observer can process only one stimulus and therefore guesses about the other. This has been rarely observed. Here we investigate such capacity limits for two measures of word recognition. Methods: In the first experiment, words appeared in rapid serial visual presentation (RSVP) simultaneously to the left and right of fixation. In separate blocks, observers either detected semantic targets (nouns belonging to a category such as "animals") or color targets (words colored slightly red). For both types of judgments we compared a dual-task condition (observers judge words on both sides) with a single-task condition (observers judge only one side and ignore the other). The second experiment was similar but used a masking paradigm with only one word presented at each location per trial. Results: In both experiments, the difference between dual- and single-task accuracy for semantic categorization was so large that it supported a serial processing model. This serial model was also supported by a negative correlation between accuracy on the two sides: judgments of one side were less accurate when the other side was judged correctly. In contrast, performance in the color detection task with identical stimuli was consistent with an unlimited-capacity, parallel processing model. Thus, the severe capacity limits are due to the requirements of the semantic task and not the stimulus properties alone. In discussion, we will contrast our new results with conflicting prior results on serial processing in word recognition.

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53.3022 The Influence of Ensemble Statistics and Focused Attention on Feature Perception

Jane Beaufore[1](beaufore.3@osu.edu), Jiageng Chen[2], Julie Golomb[1,2]; [1]Department of Neuroscience, The Ohio State University, [2]Department of Psychology, The Ohio State University

Ensemble statistics are a means by which our brains can take the average across features such as color (De Gardelle & Summerfield, 2011), size (Chong & Treisman, 2003), and texture (Alvarez & Oliva, 2009) to help us retain the gist of a scene without relying on effortful processing of every object. Other research has shown that features such as color appear to be mixed together when attention is split (Golomb et. al, 2014). We wanted to examine how focused attention versus distributed attention would influence the use of ensemble statistics and feature mixing. To test this, subjects fixated on the center of a computer screen and three squares appeared in their periphery. Either all three of the squares became bold (a distributed-attention trial) or just one became bold (a focused-attention trial), and subjects were asked to direct their attention to the bold square(s). Each square was then briefly filled with a different color, and subjects were asked to report the color of one of the squares (instructed with a post-cue) by clicking along a color wheel. Using probabilistic modeling, we found that subjects tended to report a color shifted toward the ensemble mean (the mean across all colors) in both focused-attention and distributed-attention trials, and these conditions were not significantly different. Focused-attention trials showed a decrease in overall noise, with lower standard deviations and guessing rates. Focused-attention trials also showed a decreased frequency of "swap" errors (reporting one of the distractor colors instead of the target color). These results suggest that ensemble statistics can bias the perception of features by drawing them toward the ensemble mean, and focusing spatial attention does not appear to modulate this effect.

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53.3023 Visual statistical learning faces interference from response and executive demands

Su Hyoun Park[1](suhyounp@udel.edu), Marian Berryhill[2], Jayesh Gupta[1], Timothy Vickery[1]; [1]University of Delaware, [2]University of Nevada, Reno

Associative learning of predictive relationships among visual stimuli is often referred to as "visual statistical learning" (VSL). VSL occurs in the absence of explicit awareness of such contingencies, and thus is often cast as reflecting a continuously occurring process. We found evidence that VSL faces interference from minor variations in response and executive demands, challenging the notion that VSL is a low-level, perceptual phenomenon. In Experiment 1, participants monitored a stream of face and scene images (male/female and indoor/outdoor) and responded whenever an image flickered. 16 AB pairs were repeated throughout the stream, such

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that A was 100% predictive of B. To examine the role of categorical boundaries in VSL, pairs were formed such that the items shared subcategorical status (e.g., male→male), shared categorical but not subcategorical status (indoor→outdoor), or crossed category boundaries (female→outdoor). In a surprise recognition phase, subjects were forced to pick the more familiar pairing (foil vs. target pair). Participants were above-chance and equally proficient across the different types of pairings, suggesting that visual categorical differences played little role in learning. Experiment 2 was identical, except that participants performed a categorization task during training, pressing one button if the image was a female face or an indoor scene, and a different button if it was a male face or an outdoor scene. Participants were above-chance at recognizing pairs overall, but significantly less likely to recognize pairs if they involved different responses, even if they shared categories (e.g., male→female), and also less likely to recognize pairs that involved changing task rules (e.g., male→outdoor). These results suggest that VSL is subject to interference from high-level demands, such as the requirement to make different responses across sequential trials. These findings are consistent with the interpretation that VSL, as indexed by recognition, shares mechanisms with general associative learning.

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53.3024 A system level model of visual attention: Targets and distractors are figments of your experimental design Brad Wyble[1](bwyble@gmail.com), Chloe Callahan-Flintoft[1]; [1]Psychology Department, Penn State University

Attentional capture studies provide clues as to how the visual system addresses the challenge of selecting task-relevant information, while remaining sensitive to distracting information. This ability allows us to notice unanticipated stimuli when performing a challenging visual task like driving a car. Clearly, distracting information captures attention and task-defined control settings guide attention towards relevant information, but our understanding of how these processes are implemented at the neural level is lacking. For example, in additional singleton paradigms, theories of "distractor suppression" cannot elucidate how the visual system determines which neurons should be suppressed. To better understand the neural implementation of attentional control, a system-level model of visual attention has been developed that simulates a broad set of behavioral and neural constraints (i.e. ERPs related to attention). In the model, stimuli evoke representations in an attentional map that mediates a competition between them. Attentional set is implemented as weights that bias attention towards task-relevant stimuli, but any stimulus with sufficient salience can activate attention. This model elucidates candidate attentional control mechanisms, and at the mechanism-level there are no targets or distractors per se. Rather, stimuli have varying levels of intrinsic salience and relevance to the task. The model's attention map mediates a competition between representations of those stimuli and then deploys attention to enact that decision, enhancing the winner(s) and suppressing the loser(s). The model helps to resolve ongoing debates as to whether distractor suppression is deployed as a target-surround, or selectively towards distractors. The model suggests that both occur, being differentially observable in different tasks. The model also resolves the distinction between spotlight and divided attention theories by showing that either can occur in different task contexts. Having been developed, the model now becomes part of a cyclical process of prediction, testing and model refinement.

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53.3025 No arousal-biased competition in visuospatial attention Arni Asgeirsson[1,2](arnigunnarasgeirsson@gmail.com), Sander Nieuwenhuis[2]; [1]University of Akureyri, Iceland, [2]Cognitive Psychology Unit, Leiden University

Cognitive processes, including memory, perceptual learning and decision-making, are modulated by arousal level, which can lead to positive or negative performance dependent on the experimental situation. Arousal-biased competition [ABC; Mather & Sutherland, Perspectives on Psychological Science, 6, 114-133, 2011] is a prominent theory that attempts to account for arousal modulations in a general and comprehensive manner. It states that arousal biases competitive neural processing further in favor of high priority signals at the expense of low priority ones. We investigated whether the predictions of ABC can be applied to the processes of visuospatial attention. In 4 experiments, we presented emotionally arousing or neutral stimuli (pictures or sounds) before briefly presented arrays of letters, and investigated how this affected the division of attention among stimuli of differing priority. Priority was manipulated by varying the task-relevance or physical salience of differently colored letters. Performance was assessed under varying degrees of competition for resources, including: single target identification, pop-out target identification, flanking by irrelevant salient distractors, and in multi-target divided attention tasks. Bayesian methods were used to quantify the evidence for and against the predictions of ABC theory. All 4 experiments yielded evidence in favor of the null hypothesis: that the division of attention was unaffected by the precedence of arousing stimuli, while an ERP control experiment demonstrated that the arousal manipulations were effective. Together the results suggest that the scope of ABC may not include visuospatial attention, and could be limited to cognitive processes related to the consolidation of learning and memory.

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53.3026 Display Configuration and Duration Effects in Redundancy Gain for a Categorization Task Ada Mishler[1](ada_mishler@knights.ucf.edu), Mark Neider[1]; [1]Psychology Department, College of Sciences, University of Central Florida

Redundancy gain refers to more efficient target processing when two targets are present than when one target is present. This efficiency often manifests as shorter response times (RT). Previous work has sometimes indicated a redundancy gain in target categorization tasks, and sometimes indicated no redundancy gain for such tasks. The purpose of the current study was to determine under what conditions categorical processing can benefit from redundant targets, and under what conditions it will not benefit. Participants performed a go/no-go task in which they responded only to digits rotated 45° to the left, but not to digits rotated to the right or to letters at either orientation. Each trial contained either a single stimulus or 2 redundant stimuli subtending 1° visual angle and separated by 6° visual angle. In separate blocks, stimuli were arranged unilaterally 3° to the left or right of center, along the vertical meridian, or bilaterally 3° above or below center. Accuracy was near ceiling and did not significantly differ between single and redundant targets. When stimuli were presented for 1500 ms (Experiment 1), the only significant difference between single and redundant target conditions occurred when stimuli were presented along the vertical meridian. This difference indicated a redundancy loss (single RT = 504 ms, redundant RT = 564 ms, $p = .001$). By contrast, when stimuli were presented for 100 ms (Experiment 2), the redundancy loss for vertical meridian displays remained (single RT = 444 ms, redundant RT = 485 ms, $p < .001$), but a significant redundancy gain also occurred for bilateral displays in the upper visual field (single RT = 465 ms, redundant RT = 431 ms, $p = .002$). The results indicate that interhemispheric processing may be necessary to create redundancy gain in categorization tasks, and that longer display durations may mask redundancy gain.

53.3027 Divided attention effects are larger for change detection than for simple detection James Moreland[1](jamesm37@uw.edu), John Palmer[1], Geoffrey Boynton[1]; [1]Department of Psychology, Universiry of Washington

Studies of divided visual attention have largely depended on detection and search tasks because they minimize the role of memory and decision. Recently, the change detection paradigm has been used to study divided attention and the results interpreted as due to perception. Instead, might the divided attention effects in change detection be "inflated" by memory and decision? To consider this, we compare divided attention effects for change detection and simple detection. Subjects were presented two intervals of dynamic 1/f noise patches on the left and right side of fixation and were cued beforehand to attend to either one side (selective attention) or both sides (divided attention). For the change detection task, Gabor patches were embedded in the noise on both sides, in both intervals, with a 50% chance of a 90 degree change in orientation from the first interval to the second. The probability of change was independent across sides. For the simple detection task, Gabor patches appeared in each side with 50% probability and subjects were asked to detect the presence of the patch. For the change detection task, subjects performed worse in the divided attention condition compared to the selective attention condition. However, for the simple detection task, there was almost no cost of divided attention compared to selective attention. In summary, for nearly identical stimuli, we

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show that the magnitude of divided attention effects depends strongly on the task. Ongoing studies examine whether these task effects depend only on perception or also on memory and/or decision.

53.3028 **Categorical differences in the conscious access to visual objects**

Daniel Lindh[1,2](dnllndh@gmail.com), Sara Assecondi[1], Ilja Sligte[2], Kimron Shapiro[1], Ian Charest[1]; [1]School of Psychology, University of Birmingham, UK, [2]Department of Psychology, University of Amsterdam, Netherlands

The ability to consciously recognise visual objects is crucial for adaptive behaviour and survival. Conscious access to visual objects has been studied using the Attentional Blink (AB), in which two targets (T1 and T2) are embedded with visual masks in a rapid serial visual presentation (RSVP). In the AB, the ability to detect T2 is reduced when presented 200-500ms post T1. Research using functional Magnetic Resonance Imaging (fMRI) has proven useful to identify the underlying brain mechanisms of conscious access. Given the challenges inherent to the limited temporal resolution of fMRI, researchers have designed AB-studies in which T1 and T2 targets are selected from image categories known to engage different regions in the visual stream. However, to integrate these findings into a consistent model of conscious access, the variability in detection thresholds across categories needs to be assessed. Here, we presented participants with 48 pictures of objects from several categories in an AB-task. Each picture was presented as T1, and at two different T2-lags (200ms and 700ms post T1). To compare the performance at recalling target objects across categories, we used a factorial ANOVA with T2-lag and object category as factors. We observed main effects of T2-lag ($F(1,20)=51.47$, $p < 0.001$) and category ($F(7,140)=51.6$, $p < 0.001$), along with an interaction between category and T2-lag ($F(7, 140)=27.4$, $p < 0.001$). Beyond the expected AB effect, this means that different object categories exhibit different detection thresholds. We further pooled the categories according to animate and inanimate objects, which are known to vary in their processing speeds. Here, a pairwise t-test revealed a markedly smaller AB-magnitude for animate objects ($t=4.51$, $df=37.29$, $p < 0.001$). These findings indicate a behavioural advantage for animate objects in their representational readouts, advocating for careful consideration of stimulus materials in conscious access research.

53.3029 **Three-Dimensional MOT task as an assessment tool for attention and working memory: a comparison with traditional measures**

Chiara Perico[1,2](chiara.perico@mail.mcgill.ca), Jocelyn Faubert[3], Armando Bertone[1,2,4]; [1]Perceptual Neuroscience Laboratory for Autism and Development, [2]School/Applied Child Psychology, Department of Education and Counselling Psychology, McGill University, [3]Laboratoire de psychophysique et de perception visuelle, École d'optométrie, Université de Montréal, [4]Human Development, Department of Education and Counselling Psychology, McGill University

Performance on a three-dimensional multiple object tracking (3D-MOT) task is considered to be an accurate measure of real-world dynamic attention. Working memory (WM) is an important component of 3D-MOT task completion since target items are tracked amongst distractors over a set period of time. 3D-MOT performance is also consistent with developmental expectations, wherein improvements are observed with increasing age in concordance with developing WM capabilities. This study aimed to assess whether 3D-MOT can be used to characterize WM ability at different periods of development by comparing it to that of traditional neuropsychological assessment methods. Sixty-four participants, placed in child(n=9), adolescent (n=22), adult (n=33) groups, were assessed on a 3D-MOT tasks comprised of four conditions with increasing WM load (3 target items out of 8 distractor items were tracked for 5, 8 12 and 15 seconds). All participants also completed the Paced Auditory Serial Addition Test (PASAT) WM task; attention (Connors CPT-3 & CATA) and WASI-2 IQ measures also collected. Results indicated that all groups showed a reduction in 3D-MOT performance (defined as the average speed at which target spheres were successfully tracked) with increasing WM load. Importantly, performance on the 3D-MOT and the PASAT WM task declined in a similar rate with increasing WM load for adolescents and adults, but not for children, consistent with developing WM capacity. These group differences seem to reflect the differential ability typically observed on traditional attention and WM tasks, thus suggesting that dynamic 3D-MOT tasks are sensitive enough to characterize WM ability across developmental stages.

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53.3030 **The more, the better? It depends on consistency! Gaze cuing in multi-agent contexts.**

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Humans spontaneously follow gaze of others. Here we investigated how this behavior operates in multi-agent contexts, i.e., when more than one individual is present. Social information in groups is often inconsistent such that some agents look in one direction, while others look elsewhere. How does the number of agents and the consistency of their gaze cues affect gaze following behavior? To address this question, we modified the standard gaze-cuing procedure to include three faces. On any given trial, zero, one, two, or three faces could look either to the left or to the right. Consistent trials were those on which all three faces looked in the same direction. Inconsistent trials were those on which two faces looked in the same direction while the remaining face looked in the opposite direction. Participants were asked to identify the target letter (H or N) that appeared with equal probability on the left and right side of the screen 300 or 900ms following the presentation of the cues. Results indicated that the number of agents did not affect participants' responses when social cues were inconsistent. However, the number of agents affected performance when cues were consistent, such that facilitated performance was observed when all agents looked at the target. Together these results suggest potentially important differences in how consistent and inconsistent social information affect social attentional behavior.

53.3031 **A concurrent working memory load task does not impair visual selective attention: A meta-analysis**

María Quirós-Godoy[1](maria.quirosgodoy@uam.es), Juan Botella[1], Beatriz Gil-Gómez de Liaño[1]; [1]Universidad Autónoma de Madrid

Many studies have investigated how selective attention can be modulated by information maintained in Working Memory (WM) within a dual-task paradigm. In those studies, an attentional task must be performed while a concurrent working memory load task must be done at the same time. While some studies have found that memory loads can impair attentional performance, others have not found such effects, and even a few of them have shown an improvement of attentional selection when memory is loaded. De Fockert (2013) made a first attempt to integrate the results of most of those studies. The main conclusion he made from the results of his study was that loading WM does in fact impair attention. The objective of the present study was to re-analyse most of those studies (and a few others meeting inclusion criteria) improving his work by using the meta-analytical methodology on the interaction between WM and attention. Interestingly, the main finding of the present study contradicts De Fockert's: We have found a non-significant combined effect size, that is, there is no interaction between WM and attentional processes in those dual-task studies. However, there is in fact an important heterogeneity among effect sizes ($I2 > 90\%$) worth to explore for an explanation. We discuss how several variables may have an impact modulating those effects. Finally, we have also detected an important publication bias: there is a tendency to publish significant results, leaving unpublished those studies finding no significant results. This publication bias strengthens our results, which are also in accordance with theories explaining at least part of the heterogeneous results among those studies (Olivers et al., 2011).

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53.3032 **Point me in the right direction: Lateralization of change detection in hierarchical visual stimuli.**

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The lateralization of visual processing between the hemispheres is commonly applied to hierarchical visual image processing. Lesions to the temporal-parietal left hemisphere disrupt local-level (i.e. fine detail) processing, while lesions to the temporal-parietal area of the right hemisphere lead to deficits in global-level (i.e. big picture) visual processing. Despite this, previous behavioral, functional, and event-related potential research has provided conflicting evidence for the existence of differences in the processing of visual information across the hemispheres. Some researchers have behaviorally demonstrated lateralization across the hemispheres, while others have found tenuous associations between hierarchical level, visual field, and hemispheric. Some modulating factors affecting the lateralization of hierarchical visual information have been identified. The occurrence of lateralized asymmetry may depend on stimulus category; asymmetrical processing was observed in alphabetic hierarchical stimuli, but not in hierarchical stimuli comprised of objects. The present study sought to behaviorally assess the presence of asymmetric lateralization of processing in a selective attention change-detection task using objects. Participants viewed hierarchical stimuli in the shape of an arrow. At the global level, a large arrow pointed in a certain direction while at the local level, smaller arrows pointed in a certain direction. Participants received 2 blocks of trials with an arrow to the right (left hemisphere) or left (right hemisphere) and were asked to report whether there was a change in direction of the arrow (global) or arrows (local). When global was presented first, global stimulus processing was faster and more accurate in the left hemisphere and local stimulus processing was faster and more accurate in the right hemisphere. The same differences were not apparent when the local block was presented first. There may be inherent differences between hemispheric lateralization for hierarchal change detection compared to hierarchal target detection in a selective attention task.

53.3033 **Just walk away: Gaze aversions as an overt attentional disengagement mechanism** Dekel Abeles[1](d_abeles@msn.com), Shlomit Yuval-Greenberg[1,2]; [1]School of Psychological Sciences, Tel Aviv University, [2]Sagol School of Neuroscience, Tel Aviv University

During visual exploration of a scene, the eye-gaze tends to be directed toward more salient image-locations, containing more information. However, while performing non-visual tasks, such information-seeking behavior could be detrimental to performance, as the perception of irrelevant but salient visual input may unnecessarily increase the cognitive-load. It would be therefore beneficial if during non-visual tasks, eye-gaze would be governed by a drive to reduce saliency rather than maximize it. In the current study we examined the phenomenon of gaze-aversion during non-visual tasks, which is hypothesized to act as an active avoidance mechanism. In two experiments, gaze-position was monitored by an eye-tracker while participants performed an auditory mental arithmetic task. Task-irrelevant simple motion stimuli (drifting grating and random dot kinematogram) were centrally presented, moving at varying speeds. Subjects averted their gaze away from the moving stimuli more frequently and for longer proportions of the time when the motion was faster than when it was slower. Additionally, a positive correlation was found between the task's difficulty and this aversion behavior. We conclude that gaze aversion is an active avoidance strategy, sensitive to both the physical features of the visual distractions and the cognitive load imposed by the non-visual task.

Acknowledgement: This study was funded by the Israel Science Foundation, grant 1427/14.

53.3034 **Effective task-switching behaviour despite fatigue by sleep restriction.** Gemma Hanson[1](g.hanson@soton.ac.uk), Anne Hillstrom[1], Tamaryn Menneer[1], Dominic Taunton[2]; [1]Psychology, University of Southampton, UK, [2]Southampton Marine and Maritime Institute, University of Southampton, UK

Sleep deprivation or restriction produces a tendency to conduct more exploratory behaviour (Aston-Jones & Cohen, 2005), in which there is a willingness to try new strategies (Glass et al., 2009). Voluntary task-switching strategies identified by Payne et al (2007) might therefore differ between sleep-deprived individuals and controls. Restricting sleep to 4 hours per night causes accelerated deterioration of performance (McCauley et al, 2009) with multi-tasking performance being affected after 3-5 nights (Haavisto et al, 2010). In the current study, task-switching behaviour was compared across participants whose sleep was restricted to 4 hours per night for 3 nights and participants who maintained their usual sleep pattern. The same task-switching paradigm as used by Payne et al (2007) is used, in which participants are presented with two sets of seven letters from which they are asked to generate as many words as possible. Only one set of letters is visible at a given time, and participants could freely switch between the two. Karolinska Sleepiness Scale (Åkerstedt & Gillberg, 1990) ratings were higher for the sleep-restricted than the control group. Results showed no difference between the control and sleep-restricted conditions for the number of switches made, for the number of errors made, for the types of errors made, and for the giving-up time (the time between the last word generated and the participant deciding to switch to the other task) ($\eta P2$ = .001 to .046, power = .029 to .053). A possible reason for these null results is that sleep loss impairs some aspects of cognition more than others (Killgore 2015) and the effect of fatigue on task switching does not have any impact when the task switching is voluntary, rather the effect appears when the individual is forced to switch tasks after sleep restriction (Couyoumdjian et al. 2010).

Acknowledgement: Supported by TK foundation's MARTHA Project and by Leverhulme Trust

53.3035 **Effects of Talking and Visual Attention Load on Driving Behavior** Melissa Beck[1](mbeck@lsu.edu), Rebecca Goldstein[2], Katherine Moen[3], Alex Cohen[4], Brian Wolshon[5]; [1]Psychology Department, Humanities and Social Science, Louisiana State University, [2]Psychology Department, Humanities and Social Science, Louisiana State University, [3]Psychology Department, Humanities and Social Science, Louisiana State University, [4]Psychology Department, Humanities and Social Science, Louisiana State University, [5]Department of Civil & Environmental Engineering, College of Engineering, Louisiana State University

Talking on a cell phone can impair driving performance (e.g., Stayer & Drews, 2007), but the specifics of when common attentional resources are needed are not fully understood. We examined the effects of varying the visual attention load of the driving task by manipulating familiarity with the driving environment (broad visual environment) and presence of attention demanding driving elements (specific visual targets). To vary familiarity with the driving environment, participants completed six runs through the same driving environment in a driving simulator. To vary attention to specific driving elements, there were two crosswalks with pedestrians on the side of or in the road. Half of the participants left voicemail messages on a new topic on each run (e.g., Talk about the classes your taking this semester, Talk about your favorite TV show or recent book you read) using a hands-free headset, while the other half drove in silence. In order to determine the effects of the visual attention demanding events on driving for participants who left voicemails versus those that did not, we measured velocity and steering deviation across four critical sections (45-30, 30-15, and, 15-0 meters before the crosswalks, and 0-15 meters after the crosswalks) of the last four driving runs. Leaving a voicemail increased steering deviation and velocity. However, the size of these effects decreased for the later runs, and was largest close to the crosswalks. This suggests that as more attention is needed in the visual environment, because the environment is less familiar and/or there are critical visual targets to attend to (pedestrians), leaving a voicemail leads to more erratic driving behavior (faster and more steering deviation). These results demonstrate that leaving a voicemail requires attentional resources that are also needed both for attending to the broad driving environment and for attending to specific visual targets.

Acknowledgement: U.S. Department of Transportation

ATTENTION: ELECTROPHYSIOLOGY

Tuesday, May 23, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

53.3036 **Teasing apart the extraction and the processing of visual information in the brain** Laurent Caplette[1](laurent.caplette@umontreal.ca), Karim Jerbi[1], Frédéric Gosselin[1]; [1]Département de psychologie, Université de Montréal

Humans have a limited cognitive capacity; hence, when recognizing an object or a face, they must extract different features at different moments. As such, the neuronal response to a given feature comprises responses from moments when it was attended and responses from moments when it was unattended. Responses associated with different « extraction moments » could also be different because information extracted earlier might be accumulated longer. In the present study, observers were shown faces in which the eyes and mouth were sampled at random moments during a 200ms period. They had to categorize the gender of the face while their EEG activity was recorded. To uncover activity associated with the presentation of a given feature at a given moment, we performed multiple linear regressions between feature x presentation moment sampling planes across trials and EEG activity for a given sensor at a given time point across trials. When combining responses to a given feature across all presentation moments, we reproduced the classical N170 component on parieto-occip-

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ital sensors. When breaking down this activity in responses to different presentation moments, we uncovered a highly different activity (effect of presentation moment peaking at 84 and 332ms after feature presentation, Fmax=13.58, p< .001). This indicates that information extracted at different moments is not processed in the same way and that the N170 is the result of different computations. Interestingly, this effect is not present in lower occipital sensors, which process information in the same way independently of presentation moment (p>.25; interaction between sensor and presentation moment around 328 ms, Fmax=9.15, p< .05). Our novel method allows to better understand the dynamics of visual information in the brain, from feature extraction to object recognition. Further analyses involving directional connectivity should allow us to detect the presence of gating and accumulators in the brain.

53.3037 Electrophysiological Correlates of Covert Attention Guidance in Natural Scenes

Daniel Walper[1](daniel.walper@physik.tu-chemnitz.de), Wolfgang Einhäuser[1], Anna Schubö[2], Alexandra Bendixen[3]; [1]Physics of Cognition Group, Institute of Physics, Chemnitz University of Technology, Chemnitz, Germany, [2]Cognitive Neuroscience of Perception and Action, Philipps University Marburg, Marburg, Germany, [3]Cognitive Systems Lab, Chemnitz University of Technology, Chemnitz, Germany

When observers attend a lateralized target item that is presented simultaneously with distracting visual information, a lateralized component is observed in the event-related brain potential (ERP) at about 200-300ms after stimulus onset, the so-called N2pc. While this component has been extensively studied with simple stimuli like bars and textures, the N2pc has rarely been tested for natural scenes. We presented grayscale natural scenes and noise patterns that were matched with respect to their amplitude spectrum. In some conditions ("split display"), one hemifield contained noise, the other the natural scene; in other conditions ("complete display"), either the noise or the natural scene spanned the whole display. Gabor wavelets (width (sd) of envelope: 0.6 degrees, spatial frequency: 1.9 cyc/deg) that were either tilted 30° to the left or right served as targets. In each trial, a target appeared at one of 6 distinct locations on the scene in 5.8 degrees distance from fixation. Two of the potential target locations were in each hemifield, two on the vertical midline. In each trial, target item and background were presented simultaneously, and observers had to report the orientation of the Gabor while maintaining central fixation. We found differences between the signals at electrodes contra- and ipsilateral to the target in a time window around 200ms to 280ms after stimulus onset, which correspond to the N2pc observed for simple stimuli. For both display conditions, differences in N2pc morphology were observed between targets embedded in the natural scene and targets embedded in the noise. Control analyses based on the vertical-midline targets demonstrated that these effects cannot be attributed to physical differences between natural scenes and noise. We suggest that natural scenes play a similar role as singleton distractors in simple displays, namely to capture attention that is beyond volitional control.

53.3038 The adaptation and recovery of visual event-related potentials

Hannah Glenn[1](hmglenn0893@gmail.com), Geoffrey Woodman[1]; [1]Department of Psychology, Center for Integrative and Cognitive Neuroscience, Vanderbilt Vision Research Center, Vanderbilt University, Nashville, Tennessee 37240, USA

Neural adaptation is the phenomenon in which a brain response is smaller when a stimulus is presented a second time. Although the nature of adaptation on event-related potentials (ERPs) has been studied in the auditory domain (Lu et al., 1992), there has never been a formal study of the adaptation and recovery of visual ERPs. Here, we recorded visual ERPs from participants performing a visual discrimination task in which were shown either one simple target for 100ms, or two targets separated by 500, 1000, 1500, or 1750ms. We found that the visual P1 was reduced in amplitude at the shortest lag relative to the single stimulus baseline and the longer lags. However, the amplitude of the N1 was not significantly reduced, even at the shortest lag. This indicates that even with a 400 ms inter-stimulus interval the visual ERPs show little adaptation, with only the P1 still recovering. These findings indicate the earliest visual ERPs recover from adaptation far more quickly than when measured using neuroimaging or when ERPs are elicited by other stimuli from other sensory modalities.

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53.3039 The Interplay of P1 and N1 Latency Predicts Visual Short-Term Memory Capacity, (in Absence of Pre-cue Contamination)

Bart Cooreman[1](bart.cooreman@psy.ku.dk), Anders Petersen[1], Claus Bundesen[1], Signe Vangkilde[1]; [1]University of Copenhagen

Contralateral Delay Activity (CDA) has been studied extensively as a marker of visual short-term memory (VSTM) capacity (Vogel, McCollough and Machizawa, 2005). Amongst others, the scalp topography of this ERP component and its contra-versus-ipsilateral nature suggest that the storage and maintenance of information in VSTM are cognitive operations modulating the activity in the same neural networks that are initially involved with the (biased) perceptual processing of the visual input. Hence, one would naturally predict that the quality of the initial encoding of visual information influences our ability to operate on that information for maintaining it in memory. Here, we present a latency dynamic in the early ERPs that correlates with VSTM capacity (K) and CDA amplitudes, observable when contamination of the early signal by spatial pre-cuing is adequately prevented. Our participants (N=34) verbally reported briefly shown letters in an 'early pre-cue' and 'absent pre-cue' version of a lateralized "whole report" experiment (Wiegand et al., 2014), with always five targets shown in the announced hemifield at variable exposure durations. Estimates of VSTM capacity were obtained by modeling of the accuracy data by the Theory of Visual Attention (Bundesen, 1990). Unlike a previous report, we do not replicate direct correlations between VSTM capacity and CDA amplitudes. However, we find strong correlations between memory capacity and the succession of P1 and N1 peak latency: the faster N1 follows P1, the higher a person's capacity. Interestingly, this is true for targets presented in either hemifield, but only prominent for P1 and N1 components measured at the right hemisphere – contralateral to the hemifield where the performance is weakest. In turn, this P1-N1 interplay correlates (modestly) with CDA amplitudes. Together, these results underline the role of initial encoding abilities in individuals' visual memory performance and their related CDA amplitudes.

53.3040 Alpha entrainment of posterior visual cortex impacts visual detection

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Rhythmic neural activity in the alpha band (8-13 Hz) is thought to play an important role in the selective processing of sensory information. Posterior alpha oscillations seem to regulate visual information transfer, where increased alpha amplitude reflect a concurrent increase in inhibitory mechanisms and decreased perceptual sensitivity (Klimesch et al 2007 for review). Additionally, increases in alpha frequency have been associated with heightened perceptual sensitivity both between and within subjects (Samaha & Postle 2016). However, it is unknown how alpha frequency and amplitude interact to impact behavioral performance. Here we sought to determine how changes in power across the alpha range, including at each subject's peak alpha frequency, modulate perception. To do this, we entrained neural populations using steady-state visual evoked potentials (SSVEP) in the alpha range. While recording EEG, we asked subjects to detect a brief (~16 ms) increase in the luminance of a central black fixation dot surrounded by a circular checkerboard flickering at one of eight possible frequencies in the alpha range. During this recording session, we also measured peak alpha frequency while subjects rested with their eyes closed and with their eyes open. We confirmed that subjects showed significant entrainment at each alpha frequency in posterior channels. We then found that subjects showed reduced detection performance at frequencies below, but not above, their peak alpha frequency. This implies that increasing amplitude at the peak alpha frequency does not reduce perceptual sensitivity, and suggests a more nuanced relationship between alpha frequency and alpha power in the optimal transfer of visual information.

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53.3041 Characterising the relationship between pre-stimulus individual alpha and visual search performance

Aleksandra Pastuszak[1](a.pastuszak@pgr.bham.ac.uk), Simon Hanslmayr[1], Kim Shapiro[1]; [1]University of Birmingham

Existing research indicates that performance on attentional tasks is related to anticipatory modulation of alpha oscillation (Sauseng et al., 2005). The current project explores the role of unmodulated individual alpha frequency (IAF) in target detection using reaction times (RT) in a visual search task (Treisman, et al. 1980). Decreased alpha power has been associated with improved inhibition of visual stimuli (Dijk, et al., 2008; Händel, et al., 2011). Consequently, two correlation directions could be anticipated. A positive correlation, with low IAF power related to fast RTs, cf. research wherein decreased alpha power was shown to be beneficial for single stimulus detection (Mathewson, et al., 2011). Alternatively, a negative correlation, where high IAF power would reflect the preparation for distractor inhibition (Bonneford & Jensen, 2013). The EEG signal was recorded while participants performed a visual search task which required them to detect a target among distractors. We correlated the RTs of all the trials with occipital IAF power recorded preceding the visual search onset. We have found a negative correlation between RTs and the IAF power. This suggests an inverse relationship between pre-stimulus IAF power and RTs of target detection, with higher power IAF corresponding to faster RTs, and vice versa. This is in line with research showing alpha oscillation involvement in distractor inhibition (Payne, et al., 2013; Jensen & Mazaheri, 2010). We propose pre-stimulus IAF is relevant to filtering out the unnecessary or interfering information, when target and distracting stimuli are presented concurrently.

53.3042 Attention effects on steady-state visual evoked potentials in response to 3-80 Hz flicker

Rasa Gulbinaite[1,2](rasa.gulbinaite@gmail.com), Diane Roozendaal[3], Rufin VanRullen[1,2]; [1]Université Paul Sabatier, Toulouse, France, [2]Centre de Recherche Cerveau et Cognition (CerCo), CNRS, [3]University of Amsterdam

Rhythmic visual stimuli elicit rhythmic brain responses at the frequency of the stimulus, and can be used to “frequency-tag” processing of several stimuli presented at the same time. The amplitude of steady state visual evoked potentials (SSVEPs) is modulated by attention, and SSVEP amplitude to attended stimuli is generally enhanced. Although SSVEP responses are documented for flicker frequencies up to 100 Hz [Herrmann, 2001], effects of attention on SSVEP amplitude only have been reported for lower frequencies (up to ~30 Hz), with no systematic comparison across a wide, finely sampled range of tagging frequencies. Does attention modulate SSVEP amplitude at higher flicker frequencies (e.g. gamma band, 30-80 Hz), and is attentional modulation constant across frequencies? We addressed these questions by recording EEG from twenty participants while they performed a covert spatial attention task, in which a flickering white-light LED grid had to be attended or ignored (i.e. attending a non-flickering white-light LED grid shown on the other side). Participants were instructed to detect targets (brief blue-light LED flashes) appearing in the cued hemifield (validity 80%) and ignore distractors presented in the other hemifield. Detection rate was significantly higher for validly cued trials, and targets that were presented in the left hemifield. Attentional modulation (operationalized as SSVEP amplitude difference between attend-flicker and ignore-flicker trials, normalized by the average amplitude) of the gamma-band flicker was also significantly higher for the left hemifield. Moreover, attentional modulation was positive for tagging frequencies in theta (3-7 Hz) and gamma bands, but negative for the alpha band (8-13 Hz). These effects were consistent between electrode-level and source-level analyses using linear spatial filters. In conclusion, the effects of spatial attention on SSVEP amplitude are not constant across tagging frequencies, and may depend on the interaction between flicker frequency and endogenous brain rhythms implicated in attentional processes.

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53.3043 Reactivation of a previous target location: a new event-related potential component

Hayley Lagroix[1](hlagroix@sfu.ca), Nadja Jankovic[1], Aaron Richardson[1], Kevin Boyd[1], Vincent Di Lollo[1], Thomas Spalek[1]; [1]Department of Psychology, Simon Fraser University

When two events occur in close temporal succession, processing of one can affect the processing of the other. We discovered a novel electrophysiological component that may elucidate such inter-event interactions. Participants viewed two displays (S1 and S2) shown sequentially in different locations. S1 and S2 each consisted of a target and a distractor presented either on the horizontal or vertical meridian. A pronounced event-related potential positivity, lateralized to the location of the S1 target, was evoked by the onset of S2, which appeared 100-1100 ms after S1. We refer to this component as re-activation positivity (PR). In follow-up experiments, we explored the processes that may be indexed by the PR. To examine whether the PR indexes disengagement of attention from the S1-target location upon presentation of S2, an irrelevant fixation cross was inserted in the display sequence between S1 and S2. The critical finding was that the PR was elicited by both the fixation cross and by the subsequent S2, providing evidence against an attentional disengagement account. On the alternate hypothesis that the PR represents reactivation of a spatially-specific memory of the S1 target, we examined whether the PR would occur if attention were directed to the S1-target location, but that location did not contain an item to be remembered. On half the trials, a colour oddball within a circular array of otherwise homogeneously-coloured rings contained a line segment, the orientation of which was to be remembered. On the other half of the trials, the oddball ring was empty, hence there was nothing to remember, and no response was required. The S2 display consisted of a digit presented at fixation 700 ms after S1. The PR was elicited by S2 on all trials, suggesting that maintenance of the S1-target in memory is also not essential for eliciting the PR.

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53.3044 Electrophysiological indices of target selection and distractor suppression under varying perceptual load: Evidence for spreading suppression

Zachary Roper[1](z.roper@vanderbilt.edu), Jeffrey Schall[1], Geoffrey Woodman[1]; [1]Vanderbilt Vision Research Center, Center for Cognitive and Integrative Neuroscience, Department of Psychology, Vanderbilt University

Target selection and distractor suppression mechanisms consume limited cognitive resources. The N2pc and the Pd event-related potential components index target selection and distractor suppression respectively. These two mechanisms overlap in time and are polarity inverses of each other. It is unclear whether these mechanisms compete with each other for cognitive resources, or alternatively, draw from separate resource pools. To distinguish between these competing hypotheses, we orthogonally manipulated perceptual load and the presence of a salient distractor in a visual search task. Low perceptual load displays had homogeneous distractors whereas high load displays had heterogeneous distractors. For half of all trials, one distractor was rendered salient in color. If target selection and distractor suppression mechanisms compete for resources, then searching for the target under high load will leave fewer resources to suppress the salient distractor. However, if the mechanisms are separable, then more difficult target selection will not hinder distractor suppression. Participants were slower to respond when the distractor was present, but less so for high than low load. These behavioral results replicate the load effect; however, the electrophysiological results reveal a more nuanced account. We observed no difference in the N2pc or Pd components for low and high load trials, but the mean amplitude for the combined N2pc/Pd components was larger under high load when the target and distractor were in opposite hemifields. This indicates target selection does not outright compete with distractor suppression. Rather, our results suggest that target selection is separable from distractor suppression, but that these mechanisms are not necessarily independent. Furthermore, this outcome offers an alternative interpretation to the load effect. Whereas load theory invokes attentional resource 'spill-over' to account for increased distraction in low load, our data suggest that heterogeneous distractor search involves local suppression that spreads to the distal salient distractor.

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53.3045 **Neural Correlates of Learning to Ignore** Corbin Cunningham[1](cunningham@jhu.edu), Jeff Moher[2], Annie Tran[3], James Hoffman[3], Howard Egeth[1]; [1]Department of Psychological & Brain Sciences, The Johns Hopkins University, [2]Psychology Department, Williams College, [3]Department of Psychological & Brain Sciences, University of Delaware

If you are given a direct cue to ignore specific distracting information it counterintuitively hurts rather than helps search performance (e.g. Moher & Egeth, 2012; Tsal & Makovski, 2006). However, Cunningham & Egeth (2016) recently found ignoring cues can have a benefit, given sufficient experience that facilitates learning. Early on in their experiment, cueing observers about the to-be-ignored feature (e.g., the target won't be red) slowed RTs compared to a neutral control condition. However, as observers learned the specific to-be-ignored feature over time, RTs were much faster on these "ignore" trials compared to "neutral" trials. While Cunningham and Egeth (2016) found a behavioral benefit to learning to ignore, the attentional mechanisms that support this behavior remain unclear. Therefore, we used electroencephalographic recordings to investigate the neural mechanisms of attention supporting this pattern of behavior. In the present study, observers performed a search task in which a single target letter was presented among 11 non-target letters on each trial. Six of the letters shared the same majority color (e.g., red) while the other six were shown in random heterogeneous colors. On half the trials, a pre-trial cue validly instructed participants to ignore a particular distractor color (e.g., "Ignore Red") which corresponded to the 6 items in the majority color. On the other half of trials, the pre-trial cue provided no information (i.e., "Neutral"). We replicated the behavioral results of Cunningham & Egeth (2016). Critically, while the behavioral data show a clear benefit from learning to ignore, we observed patterns of neural activity related to an initial shift of selective attention towards the to-be-ignored objects (e.g., N2pc), suggesting that selective attention is still a part of directed ignoring even after sufficient learning. Our results demonstrate that the benefit from learning to ignore might arise from rapidly shifting attention to the to-be-ignored items.

53.3046 **High definition transcranial alternating current stimulation reveals different frontal oscillatory mechanisms of visual-feedback processing and learning** Robert Reinhart[1](rmgr@bu.edu); [1]Department of Psychological & Brain Sciences, Center for Systems Neuroscience, Center for Research in Sensory Communications, Boston University, Boston, MA 02215, USA

Learning to adapt behavior based on changes in the visual environment is a hallmark of human visual cognition and implicated in a variety of neuropsychiatric disorders. Here, we examined the role of different frontal oscillatory mechanisms using high-density electroencephalography (EEG). Human subjects performed a probabilistic cognitive reinforcement learning task that allowed us to distinguish individuals based on their motivational baises to learn by avoiding negative feedback versus pursuing positive outcomes. We found that negative feedback related theta power (4 - 8 Hz) in medial-frontal regions was stronger in negative learners, whereas positive feedback related beta power (18 - 24 Hz) in ventral-medial regions was stronger in positive learners. Brain-behavior correlations showed that individual preferential biases to learn more from negative than positive feedback were associated with relatively more medial-frontal theta power, whereas biases to learn more from positive than negative feedback were related to relatively greater ventral-medial beta power. To further examine whether mechanisms of feedback valence were distinguished in frequency-brain space, we sought to manipulate the medial-frontal theta effect using 4 Hz high definition transcranial alternating current stimulation (HD-tACS). This noninvasive stimulation selectively disrupted medial-frontal theta and negative-learning behavior, leading to performance impairments in negative learners. However, no such stimulation-induced changes were observed in ventral-medial beta rhythms or positive-learning behavior, resulting in the stimulation having no significant impact on individuals who learned by pursuing positive outcomes. The results provide new evidence for theories in visual cognition that propose separate neurophysiological mechanisms underlie choice-behavior and learning guided by visual information from the environment. The results also show that alternating current can be used to manipulate the signal power of ongoing neural oscillations in frontal cortex important for executive control and decision-making.

53.3047 **Electrophysiological indices of value-driven attentional capture extinction** Shelby Santee[1](shelbysantee@gmail.com), Zachary Roper[1], Geoffrey Woodman[1], Keisuke Fukuda[2]; [1]Department of Psychology, Vanderbilt Vision Research Center, Vanderbilt University, [2]Department of Psychology, University of Toronto Mississauga

In daily life, individuals encounter many stimuli that predict rewarding outcomes. Such stimuli can have a powerful impact on behavior. For example, value-driven attentional capture occurs when a previously reward-predictive stimulus pulls attention away from the current task (Anderson et al., 2012). Although much is known about the acquisition of stimulus-reward associations, the extinction of such associations is less clear. Here we examined how feedback facilitates the extinction of learned stimulus-reward associations. Participants first learned to associate specific color-shape combinations with reward to earn as many points as possible. Our results indicated that participants consistently chose the high reward color for each shape during the initial training phase. Subsequent to the training phase, participants completed a testing phase where no rewards were delivered and participants demonstrated strong indices of value-driven attentional capture (i.e., an N2pc ERP component to the previously rewarding stimuli and a distraction effect in RT). Next, participants performed a second training phase where the initially rewarding stimuli were remapped to new outcomes. This was done in three ways: (1) high reward to high reward, high reward to low reward and high reward to high punishment. After the remapping procedure, participants consistently attended the high reward color (i.e., N2pc) and avoided the high punishment color (i.e., eliciting the Pd ERP component indicating distractor suppression). Our results show that reward extinction is fastest when the previously rewarding stimulus is paired with punishment. However, merely removing reward from a pairing was sufficient to bring an individual's desire to choose that previously rewarding item down to baseline indicating that reward associations used in vision laboratories can be rapidly extinguished when reward contingencies return to normal in the real world.

53.3048 **Task dependent modulation before, during and after visually evoked responses in human intracranial recordings** Leyla Isik[1,2](lisik@mit.edu), William Lotter[1,3], Nathan Crone[4], David Cox[2], Nancy Kanwisher[2], Wiliam Andreson[4], Gabriel Kreiman[1]; [1]Boston Children's Hospital, Harvard Medical School, [2]Massachusetts Institute of Technology, [3]Harvard University, [4]Johns Hopkins School of Medicine

We can effortlessly answer many questions about the same visual stimulus. Standard models of visual recognition describe the sequence of processing steps that occur along the ventral visual stream during the first 150 ms after stimulus onset. When and where in the brain does processing start to depend on task? Here we examined the effect of task on visual processing by recording intracranial electrocorticography (ECoG) data from 1176 electrodes in ten epilepsy patients. Subjects were presented with synthetically generated face stimuli and were instructed to perform one of two possible two-alternative categorization tasks (Fig. 1): age (old/young) or gender (male/female). We measured the modulation of visually evoked responses by task before, during and after image presentation. The high gamma power in 50 visually-responsive electrodes differed between age and gender tasks, despite identical images being present in both tasks. Fourteen electrodes showed these task modulations early on, essentially concomitant with the onset of the visual responses. Thirty-seven electrodes showed late task modulation, after the initial visual evoked response. Intriguingly, we also observed 15 electrodes that showed sustained task modulation before image onset during the "Fixation" period (Fig. 1). These observations show that task modulates visual responses before, during, and after the initial visual response to the stimulus. This progression from pre-stimulus cuing to post-stimulus task representations provides an initial map of the sequence of operations used to transform identical visual inputs into different types of task related information.

Perception and Action: Mutual interactions

Tuesday, May 23, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.4001 Postural reactions to inclined visual ground-like surfaces

Konogan Baranton[1](barantok@essilor.fr), Delphine Bernardin[1], Mark Wexler[2]; [1]Essilor International, R&D, Vision Sciences, Paris, France, [2]Laboratoire Psychologie de la Perception, Université Paris Descartes and Centre National de Recherche Scientifique, Paris, France

The perception and control of body orientation is based on the ability to align body axes with gravity directions on surrogates axes such as visual ground surface. We hypothesized a 'horizontality assumption': similarly to vertical surfaces moving in depth (Lee & Aronson, 1974), a slight inclination of the ground will induce postural adjustments in the direction of the surface norm, in order to regain the visually assumed upright orientation. We tested this hypothesis in an experiment that took place in a virtual reality system free of extraneous visual gravity cues. The stimulus consisted of a 20x20 m ground-like surface, textured with an irregular mesh, presented with binocular disparity. In the static condition, the surface was presented 3 times with 4 slants from 2.5 to 20 deg deviation from the horizontal, and 5 tilts, the direction of maximum inclination, from -45 to +45 deg from straight ahead. In the dynamic condition, the surface was initially presented horizontally, and gradually inclined to same orientations. We measured center of pressure (COP) using a Wii Balance Board. We fitted COP trajectories by 95% confidence ellipses, and performed a linear regression between the angle of major axis and surface tilt, in order to quantify how postural reactions are aligned with the direction of surface inclination. In the static condition, mean slope was 0.21 (p=0.04, signed-rank test), with the correlation significantly strongest for slant of 5 deg. In the dynamic condition, mean slope was 0.55 (p=0.03), with a maximum at slant 10 deg. Time evolution of the regression slope indicates a delay followed by a plateau in the static condition, and an immediate and continuous rise in the dynamic condition. These results support the horizontality assumption in both dynamic and static conditions, but with postural reactions about two times smaller in the static condition.

53.4002 The role of motion parallax in the perception of egocentric direction

Kait Clark[1](clarkk3@cardiff.ac.uk), Simon Rushton[1]; [1]School of Psychology, Cardiff University

Prisms optically rotate the visual scene relative to the head, but the error in perceived direction that results is less than the optical deflection of the prism. This is known as the immediate correction effect (Rock, Goldberg, & Mack, 1966). The effect could result from cues provided by knowledge of the surrounding environment, and indeed, a recent study found that the immediate correction effect is reduced in the dark (Pochopien & Fahle, 2015). Here we tested an alternative hypothesis: the immediate correction effect is driven by motion parallax resulting from movements of the head, and motion parallax (the speed of head-centric motion that results from a head rotation) is a function of the direction of the object relative to the head. Accordingly, the light/dark effect would result would from the more precise relative motion signals available in the light. Our hypothesis would also predict two other patterns of behaviour: the immediate correction effect should reduce with the distance of the target (motion parallax reduces with distance), and the immediate correction effect should be reduced if the target is only transiently visible (removal of motion signal). We presented participants with illuminated target objects while they wore horizontally shifting prism glasses. Participants were instructed to orient their heads and bodies to face the target objects, and we recorded positional information via a motion-tracking system. We compared orientation errors for targets placed at varying distances when the room was lit, dark, and when the targets were flashing in the dark. As predicted, the immediate correction varied as a function of target distance. Second, the immediate correction effect was larger in the light than in the dark. Third, the dependence of the magnitude of the immediate correction effect on distance was abolished when the target was only transiently visible.

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Tuesday AM

53.4003 Spatial Representation for a Non-Euclidean Virtual Maze

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One of the basic properties of space is its curvature, i.e. whether it is Euclidean (flat) or not (curved). The present study examined how people represent non-Euclidean space using two virtual tunnel mazes. One maze formed a square shape (Euclidean space), while the other contained a shortened path segment using a portal so that the overall maze violated the principles of Euclidean geometry. Each segment contained two landmarks. Participants learned the mazes by freely traversing the paths using a virtual reality HMD, and completed a pointing task and map-drawing task. Items in the pointing task were separated into local and global landmark pairs and tested independently. The local landmark pairs were adjacent but in different segments. The global landmark pairs were in opposite segments. The pointing responses for each landmark pair were compared to the corresponding directions indicated in each participant's drawn map and three hypothetical Euclidean maps that preserve the maximum amount of spatial relations by lengthening the shortened segment. They differ in how the two landmarks were placed in the lengthened segment. One placed the landmarks at the same distance from their nearest corner (corner map), one placed them proportionally in the lengthened segment (scale map), and one placed them in the mean position relative to the two corners (mean position map). The mean errors of the pointing directions relative to each of these four maps were calculated to assess the underlying representation guiding the pointing responses. The data showed that the egocentric pointing judgments were most similar to the corner map, with errors comparable to those of the regular square maze, and significantly different from their own drawn map, especially for the local landmark pairs, suggesting people's pointing judgments in a globally non-Euclidean maze resemble an underlying Euclidean map that preserves landmark distance from the nearest corners.

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53.4004 The bigger the better – also true for action recognition?

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In a previous study, we have investigated action recognition performance in central vision and far visual periphery under close-to-natural conditions, i.e. using moving life-size avatars (Fademrecht, Bülthoff, and de la Rosa 2016). We found a non-linear decline of action recognition performance: recognition performance did not decline significantly up to 45° eccentricity and then declined steadily up to 60° eccentricity. To our best knowledge, such a recognition pattern has not been observed with other stimuli, like objects or faces. However, it is well known that stimulus size positively influences visual recognition performance in the visual periphery. Here, we tested recognition of life-size (30° visual angle) and small (6° visual angle) moving avatars to investigate whether the remarkably good recognition performance in the periphery was simply owed to stimulus size. We find a steeper decline of recognition performance with eccentricity for small stimuli compared to large stimuli. However, accuracy was above chance level up to 75° eccentricity for large stimuli, and up to 60° for small stimuli. These results show a surprisingly high recognition performance for human actions in the visual periphery even when the stimuli are small. Hence, bigger action stimuli are better recognized in far visual periphery, although even for small stimuli recognition performance is remarkable.

53.4005 The neural correlates of hand and foot action recognition in individuals born without upper limbs

Moritz Wurm[1,2](moritz.f.wurm@gmail.com), Gilles Vannuscorps[1], Ella Striem-Amit[1], Alfonso Caramazza[1,2]; [1]Department of Psychology, Harvard University, [2]Center for Mind/Brain Sciences, University of Trento

Do we need the motor system to process and recognize the actions of others? According to motor theories we recognize actions by covertly imitating observed actions. This view has recently been challenged by two lines of evidence: neuroimaging studies show that the lateral occipitotemporal cortex (LOTC) and inferior parietal lobe (IPL) encode feature-invariant action representations whereas premotor cortex (PMC) seems to code concrete action features only; furthermore, behavioral studies demonstrate that individuals born without upper limbs recognize hand actions, that they cannot covertly imitate, with the same efficiency as control participants. However, it could be that in typically developed individuals access to higher level hand action representations in LOTC and IPL is subsequent to motor simulation of concrete actions in PMC, and that in subjects without upper limbs access to those higher level representations is based on different (compensatory) neurocognitive mechanisms drawing on other brain regions like the mentalizing network. This fMRI study aimed at addressing these possibilities. We scanned five dysplasic individuals (IDs) born without upper limbs and typically developed participants when watching videos of actions executed with lower and upper limbs (open and close doors and trash bins). We found similar significant decoding of hand actions in LOTC and IPL of both the IDs and the controls, demonstrating that access to higher level action representations in LOTC and IPL does not require motor simulation. Second, at odds with the hypothesis that the IDs recruit compensatory neurocognitive mechanisms to recognize hand actions, we found similar neural activity and cluster locations in PMC, LOTC, and IPL with regard to hand and foot actions in the IDs and the controls, and no trace of increased neural activity or decoding of hand actions in other brain regions of the IDs. These findings suggest that action recognition relies on visual, not motor, processing.

53.4006 **Low and high level features explain neural response tuning during action observation** Leyla Tarhan[1](ltarhan@g.harvard.edu), Talia Konkle[1]; [1]Department of Psychology, Harvard University

Among humans' cognitive faculties, the ability to process others' actions is essential. We can recognize the meaning behind running, eating, and finer movements like tool use. How does the visual system process and transform information about actions? To explore this question, we collected 120 action videos, spanning a range of every-day activities sampled from the American Time Use Survey. Next, we used behavioral ratings and computational approaches to measure how these videos vary within three distinct feature spaces: visual shape features ("gist"), kinematic features (e.g., body parts involved), and intentional features (e.g., used to communicate). Finally, using fMRI, we obtained neural responses for each of these 2.5s action clips in 9 participants. To analyze the structure in these neural responses, we used an encoding-model approach (Mitchell et al., 2008) to fit tuning models for each voxel along each feature space, and assess how well each model predicts responses to individual actions. We found that a large proportion of cortex along the intraparietal sulcus and occipitotemporal surface was moderately well fit by all three models (median r=0.23-0.31). In a leave-two-out validation procedure, all three models could accurately classify between two action videos in ventral and dorsal stream sectors (65-80%, SEM=1.1%-2.6%). In addition, we observed a significant shift in classification accuracy between early visual cortex (EVC) and higher-level visual cortex: the gist model best in early visual cortex, whereas the high-level models out-performed gist in occipito-temporal and parietal regions. These results demonstrate action representations can be successfully predicted using an encoding-model approach. More broadly, the pattern of fits for different feature models reveals that visual information is transformed from low- to high-level representational spaces in the course of action processing. These findings begin to formalize the progression of the kinds of action information being processed along the visual stream.

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53.4007 **The Visual Perception of Interactive Behaviour in the Posterior Superior Temporal Cortex** Jon Walbrin[1](j.walbrin@bangor.ac.uk), Paul Downing[1], Kami Koldewyn[1]; [1]Bangor University, Wales

Previous evidence demonstrates that the posterior superior temporal sulcus (pSTS) plays a central role in the perception of social interactions (Georgescu et al., 2014). However, it is unknown whether this region discriminates between different types of interactions. Additionally, pSTS activation is also modulated by other social processes, such as theory of mind (ToM) attribution (Schurz et al., 2014) and body perception (Deen et al., 2015), and it is unclear whether these processes are necessary to perceive interactive behaviour. Using interactive shape stimuli (i.e. 2 animated circles that convey intentional behaviour) along with an orthogonal response task to limit explicit mentalizing, two hypotheses were posed: 1) pSTS activity will differentiate interactions from non-interactions; 2) pSTS activity will differentiate cooperative from competitive interactions. Multivariate support vector machine analysis was implemented for whole-brain searchlight analysis and within 3 regions of interest (ROI): The pSTS and temporo-parietal junction (TPJ) were defined with independent localizer tasks (i.e. human interaction and false belief tasks, respectively) to determine whether these regions differed in response to interactive shape stimuli; following searchlight analysis, an additional post-hoc ROI – the posterior superior temporal gyrus (pSTG) – was independently defined. For the cooperation vs. competition contrast, searchlight analysis revealed a single cluster in the right pSTG, along with above-chance classification in the pSTG and pSTS (>55%; ps < .05), but not TPJ. For the interaction vs. non-interaction contrast, searchlight analysis revealed a bilateral network along with right pSTS activity, and above-chance classification (>59%; ps < .05) in all 3 ROIs. These findings cannot easily be attributed to human body information or explicit mentalizing (i.e. interaction sensitivity was relatively weaker in TPJ, and the orthogonal task limited explicit ToM inferences); therefore, these results implicate the posterior superior temporal cortex as a central region in the visual perception of interactive behavior.

53.4008 **Videos are more effective than pictures at localizing tool- and hand-selective activation in fMRI** Scott Macdonald[1](smacd49@uwo.ca), Fiona van den Heiligenberg[2], Tamar Makin[2], Jody Culham[1]; [1]Neuroscience, Western University, [2]Nuffield Department of Clinical Neurosciences, Oxford University

Areas implicated in tool and hand processing have typically been localized by contrasting pictures of tools and hands to pictures of animals, objects, or scrambled images during functional magnetic resonance imaging (fMRI). Dynamic stimuli like videos, however, may be advantageous as they are more engaging than pictures and can depict the complex interaction between an effector and its target. The purpose of this project was to determine whether videos are indeed more effective than pictures in identifying tool- and hand- selective activation. In two experiments, healthy participants were scanned as they watched videos and pictures. In Experiment 1, we compared a typical fMRI localizer with pictures of tools, hands, objects, and scrambled images (all in isolation, centred within a neutral background) to movie clips that showed tools interacting with objects, hands manipulating objects, objects in motion, and moving patterns (akin to a scrambled condition). The results from Experiment 1 demonstrated that videos activated a more extensive tool- and hand-selective network than traditional pictures (based on the contrast tool/handvideo – objectvideo) > (tool/handstatic > objectstatic). However, because there were numerous differences between the picture and video stimuli in Experiment 1, we ran a second experiment in which the stimuli were directly comparable. In Experiment 2, participants viewed the same categories of videos as in Experiment 1 or static frames from those videos. We again found much more extensive tool- and hand-selective activation for videos compared to pictures. Moreover, across both experiments, videos were more effective at identifying tool- and hand-selective activation in individual participants, making them more suitable as fMRI localizers (now publically available). We conclude then that videos are more effective than pictures at representing the action information evoked by observing the interaction between an effector and its target, especially in brain areas involved in actions and goal-oriented behaviour.

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53.4009 **Visual production induces categorical perception** Judith Fan[1,2](jefan@princeton.edu), Daniel Yamins[3,4], Nicholas Turk-Browne[1,2]; [1]Department of Psychology, Princeton University, [2]Princeton Neuroscience Institute, Princeton University, [3]Department of Psychology, Stanford University, [4]Stanford Neurosciences Institute, Stanford University

In the study of language, production has long been viewed as essential for understanding comprehension. By contrast, vision science has centered almost exclusively on comprehension (recognition) and has largely neglected production. Here we investigate visual production in its most basic form — drawing. We test the hypothesis that repeatedly drawing an object differentiates its representation from other objects, making it more perceptually discriminable. This hypothesis is motivated by our previous findings that: (1) a deep neural network model of the ventral visual stream trained purely on photographs also recognized drawings, reflecting a common feature representation of objects across production and recognition; and (2) training people to draw improved the model's ability to recognize

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their drawings, resulting from reduced feature overlap in the representations of different objects. The current study directly evaluates how learning to draw affects human object recognition, using a categorical perception task sensitive to such representational changes. Participants alternated between drawing two Trained objects (e.g., bed and bench), and did not draw an additional two Control objects (e.g., table and chair). Before and after training, participants categorized morphs of the two Trained and the two Control objects. Insofar as drawing differentiated Trained object representations, resulting in less feature overlap between them, intermediate morphs should be recognized according to the distinguishing features of the dominant object in the morph, and perception should become more categorical. Indeed, learning to draw the Trained objects increased the slope of the psychometric curve fitted to categorization responses, suggesting enhanced perceptual discriminability. This was not observed for the Control objects, nor in a separate experiment in which participants watched others draw rather than drawing themselves. Thus, beyond perceptual experience, the act of drawing itself helps refine our object concepts.

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53.4010 **An fMRI analysis of subjective experience during immersive gaming** Christian Wallraven[1](christian.wallraven@gmail.com), Uijong Ju[1]; [1]Cognitive Systems, Korea University

A large number of perceptual and cognitive processes are activated during game play. Previous studies have identified seven core dimensions of such processes: competence, immersion, flow, tension, challenge, and positive and negative affect. Although research has begun to investigate neural correlates of individual dimensions, the brain patterns related to the full range of these subjective game experiences so far has not yet been studied. In the present research, we assess subjective game play experience in fMRI using a custom-made, immersive driving game, in which we explicitly vary the game mechanics to induce different levels of game experience. In all versions of the game, the task was to navigate a race course, while collecting bonus tokens and avoiding obstacles. There were four, 3-minute versions of the game that manipulated different aspects of game experience: baseline, difficult (increased obstacles), goal-decreased (decreased bonus tokens), and speeded (increased car acceleration). Participants (N=18) played the baseline version first, followed by random presentation of the other three versions with 30s break-times in-between. Stimulus presentation in the fMRI-scanner used stereo-enabled goggles (800x600px, 60fps) and game-sounds presented via headphones. After the experiment, the seven dimensions of game experience were assessed using a standard questionnaire (GEQ). Beta-values for each of the four conditions were correlated in a whole-brain, FDR-corrected correlation analysis with each of the seven questionnaire dimensions. In addition, an MVPA-based correlational analysis was conducted for participants based on a 4x4 similarity matrix created by evaluating the Euclidean distances of the seven-dimensional rating vectors. Results show significant activations for positive affect, competence, flow and challenge in dorsal and ventral pathways (BA17,18,19 and BA7,37,39,40). The MVPA-analysis confirmed these regions and also showed significant activations in the frontal lobe. Our results for the first time identify the perceptual, motivational, and control networks engaged during active, immersive game play.

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53.4011 **Braking bad: Arousal influences the visual guidance of braking** Brandon Thomas[1](brandonjthomas47@gmail.com), Micheal Guess[2], Ian Ruginski[1], Jeanine Stefanucci[1]; [1]Deparement of Psychology, University of Utah, [2]Max Plank Institute for Biological Cybernetics

Arousal has been shown to influence perceptual judgments as well as the execution of online motor control (e.g., as in the case of choking under pressure). The current study investigated whether arousal also influences the online control of a common visually-guided action over time. Participants performed either an emergency (Experiment 1) or regulated (Experiment 2) braking task with the goal of stopping before colliding with a target. For the emergency braking task, participants applied maximum braking pressure and once braking pressure was applied it could not be released. For regulated braking, participants were able to adjust braking pressure as needed over time. Participants performed one braking task after arousal induction or not. We were primarily interested in testing the hypothesis of whether arousal altered the calibration between visual information and action execution. We hypothesized that arousal would indeed act as a soft constraint on motor control (Harrison, Frank, & Turvey, 2016). Behaviorally, we hypothesized that arousal would lead to faster initiation of braking and less crashing, by influencing the perceptual-motor calibration of braking with respect to visual information. Results from emergency braking supported our hypotheses — anxious participants initiated braking sooner and crashed less often. However, when performing regulated braking, anxious participants initiated braking sooner but crashed more often. Overall, the results demonstrated that participants were more conservative in their braking, but that this actually led to a greater chance of crashing when braking was continuously regulated because of their greater reliance on current braking. These results imply that emotions act to alter the calibration between perception and action. Future work may benefit from integrating continuous, physiological indicators of emotional states.

Face Perception: Individual differences, learning and experience

Tuesday, May 23, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.4012 **Systematic variations in visual information utilization predict face recognition abilities, from developmental prosopagnosics to super-recognizers** Jessica Tardif[1](jessica.tardif.1@umontreal.ca), Xavier Morin Duchesne[2], Brad Duchaine[3], Caroline Blais[4], Frédéric Gosselin[1]; [1]Département de psychologie, Université de Montréal, [2]School of Psychological and Brain Sciences, Indiana University, [3]Department of Psychological and Brain Sciences, Dartmouth College , [4]Département de psychologie et psychoéducation, Université du Québec en Outaouais

Face recognition abilities vary greatly among neurotypical people, but the causes of these variations are not well understood. Here, we show that for face recognition, the use of specific visual information from faces predicts abilities for identifying faces. Abilities were measured in 96 adult participants prior to evaluating the visual information they use. Included in these participants were two developmental prosopagnosics (DP) and six super-recognizers (SR): groups of people with extraordinarily low (DP) or great (SR) face recognition abilities. These two groups represent extremes of the ability spectrum. Utilization of visual information was assessed using the Bubbles method. In 1000 trials, participants were asked to identify a known celebrity's face. The stimuli were spatially sampled by applying a mask with randomly positioned Gaussian windows (bubbles) revealing visual information from the faces at five spatial scales. A regression was then applied between the sampled information and accuracy on each trial, determining which information was systematically sampled from each of the scales when participants correctly identified faces. The result is a z-scored classification image showing visual information used by each participant. Subsequently, the pixels in these classification images were divided in a regular grid containing 35 rectangles. A second-order regression was then applied between ability scores and average z-scores of utilization of pixels in each rectangle, for each scale. In the two finest scales, the extent at which specific spatial visual information is used can predict abilities. In the finest scale (28-56 cycles per face [cpf]), best predictors are the eye areas, nose and left side of face (adjusted R-squared=0.34; p=.002). In the second finest (14-28 cpf), the best predictor is the use of the left eye (adjusted R-squared=0.44; p< .001). We conclude that individual differences in face recognition abilities are partly explained by the extent at which specific face information is used.

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53.4013 **Individual differences in children's face recognition abilities** Romina Palermo[1,2](romina.palermo@uwa.edu.au), Marianne Thorburn[2], Ellen Bothe[1,2], Laura Engfors[1,2], Amber King[2], Kaitlyn Turbett[1,2], Xujia Wang[1,2], Prue Watson[1,2], Linda Jeffery[1,2]; [1]ARC Centre of Excellence in Cognition and its Disorders, [2]School of Psychological Science, University of Western Australia, Perth, WA, 6009, Australia

Accurate face identity recognition is crucial to social functioning. Despite this, there are considerable individual differences in this ability among the general population. In adults, these differences are primarily argued to reflect variation in face-specific perceptual and cognitive mechanisms, with only small contributions from more general cognitive abilities. Research has focused on the role of two face-sensitive perceptual mechanisms: holis-

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tic coding (in which information is integrated across a face) and adaptive norm-based coding (in which faces are coded relative to a norm in a multidimensional face-space and that norm is updated by experience), and shown that variation in the strength of these two mechanisms is associated with individual differences in face recognition abilities. In contrast, little is known about what contributes to individual differences in face recognition abilities in children. Performance on tests of face recognition improves with age, from preschool until adolescence, suggesting that face recognition skills mature during childhood. Nevertheless, children rely on the same face-sensitive perceptual mechanisms as adults, suggesting that individual differences in children's face recognition abilities may also be associated with variation in these mechanisms. However, given arguments that improvements in more general cognitive abilities may underlie the age-related improvements in face recognition ability, it is also plausible that variation in more general cognitive skills may make a more substantial contribution to children's, than adults, face recognition abilities. We examined the contributions of holistic processing and adaptive norm-based coding, along with general cognitive abilities, to individual differences in face recognition ability in over 150 children aged 6–9 years. Face recognition abilities were associated with the strength of both perceptual mechanisms but not cognitive abilities, when age was controlled for. These results indicate that face-sensitive perceptual mechanisms contribute to face recognition abilities by age six and suggest that this relationship potentially remains consistent throughout development.

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53.4014 Individual differences in face processing ability and consistency in visual strategies

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Individual differences in face processing ability are a useful tool to better understand the cognitive and perceptual mechanisms involved in optimal face processing (e.g. see Yovel et al., 2014). We recently showed using the Bubbles technique (Gosselin & Schyns, 2001) that these individual differences are linked to a quantitative increase in the use of the eye area of faces, a feature known to be highly diagnostic for accurate face recognition (Royer et al., VSS 2016 meeting). However, no specific visual strategy was found in the lower recognition ability observers, possibly due to the use of inconsistent visual strategies in these individuals. This inconsistency could manifest at different levels, namely (1) between subjects, i.e. lower ability individuals rely on idiosyncratic recognition strategies, or (2) within subjects, i.e. lower ability individuals show an unstable pattern of diagnostic information throughout the bubbles task. The present experiment directly investigates these propositions. Fifty participants (28 women) were first asked to complete 2000 trials of a 10-alternative forced choice face recognition task in which the stimuli were randomly sampled using Bubbles. All participants also completed three common face matching and recognition tests to quantify their face processing ability. First, between-subject consistency in visual strategies in observers with similar levels of identification performance was strongly correlated with general face processing ability ($r = .69$; $p < .001$). Moreover, this inconsistency in visual strategies was also present at the within-subject level. Indeed, face processing ability was also significantly correlated with each observer's level of consistency in their own visual strategies throughout the bubbles task ($r = .42$; $p = .002$). These results demonstrate that while higher ability face recognizers consistently use a similar and stable strategy to recognize faces, lower ability individuals instead rely on idiosyncratic and varying strategies, possibly reflecting the imprecision of their facial representations.

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53.4015 Familiarity abolishes right-hemispheric bias in face perception

Katja Weibert[1](kw783@york.ac.uk), Veronika Müller [1], Jessica Sänger[1]; [1]Experimental Biological Psychology, Heinrich Heine University Düsseldorf

Perception of unfamiliar faces is right-lateralised. However, familiar faces have been reported to be processed differently: familiar faces activate the left hemisphere more strongly than unfamiliar faces. This difference has been proposed to reflect higher processing of verbal information associated with familiar faces, e.g. the name. However, it remains unclear whether this increased left-hemispheric processing of familiar faces has an effect on how familiar faces are perceived. Therefore our study investigated the effect familiarity has on the right-hemispheric bias in face perception. To address this question, chimeric faces of familiar and unfamiliar faces were used. Familiar faces depicted pictures of celebrities participants could name. Since pictures of celebrities might differ from unfamiliar faces, e.g. be more symmetrical, we used pictures of celebrities unknown to the participants as our unknown faces. Next, chimeric faces were created by splitting a face image into a left and right half, and then mirroring each. This resulted in two new images. One image contained solely information of the left image half of the original (left chimeric) processed by the right hemisphere. Whilst the other image contained solely information of the right image half of the original (right chimeric) processed by the left hemisphere. To measure lateralisation of face perception, participants were asked to choose which chimeric face looked more like the original face. A preference for the left chimeric would suggest a right-hemispheric bias. In line with previous literature, participants preferred the left chimeric when unfamiliar faces were used supporting the known right-hemispheric bias for the perception of unfamiliar faces. However, familiar faces did not elicit a bias in perception: no preference for either chimeric face emerged. Thus, familiarity seems to change how faces are perceived. Familiar faces seem to be perceived more bilaterally, potentially due to an increased activation of the left hemisphere.

53.4016 Task effects on perceived identity of unfamiliar faces in open card sorting.

Alison Campbell[1](campbel1@uvic.ca), James Tanaka[1]; [1]University of Victoria, Canada

Face perception is tantamount to identity perception. While identity representations in memory can be engaged to categorize different images of a familiar face (e.g., Barack Obama, George Clooney) with little interference from superficial variations in appearance and lighting, images of an unfamiliar face can be categorized only on the basis of perceptual information in the image. The difference in identity perception in familiar and unfamiliar face images is captured in a face sorting task where observers often perceive different images of the same person as different identities, but only when the face is unfamiliar (e.g., Jenkins et al., 2011; Neil et al., 2016). The current research addresses whether the formation of sub-identities of unfamiliar persons are idiosyncratic or systematic and whether the nature of the sorting task itself influences judgements of identity. In this study, participants were presented with 40 face images either simultaneously or sequentially and asked to group the images according to identity. Replicating previous results (Jenkins et al., 2011), participants tended to overestimate the number of identities in the face images ($M = 6.35$, $SD = 5.76$; 2 identities in the set). Jaccard similarity coefficients showed that participants in the simultaneous group were reliably more accurate than participants in the sequential group ($p = .01$). Hierarchical cluster analysis revealed shared sorting strategies amongst participants, however categorization structures diverged across conditions with respect to both the size and composition of the clusters. Results suggest that perceived identity of an unfamiliar face may be based on predictable parameters (e.g. hair, makeup, lighting), but that those parameters may change depending on the demands and procedures of the categorization task.

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53.4017 The influence of temporal contiguity on behavioral and neural measures of viewpoint tolerance

Chayenne Van Meel[1](chayenne.vanmeel@kuleuven.be), Hans Op de Beeck[1]; [1]Brain and Cognition, University of Leuven, Belgium

Humans can reliably recognize faces across viewpoints. Although suboptimal, their performance is quite remarkable given the large changes in low-level image properties a shift in viewpoint introduces. We used a behavioral and an fMRI adaptation experiment to investigate whether this viewpoint tolerance is reflected in the neural visual system and whether it can be manipulated through training. Participants saw training sequences of faces displayed in 7 different rotation angles, creating the appearance of a rotating head. Half of the sequences showed faces undergoing veridical changes in appearance across the rotation (non-morph condition). The other half were non-veridical: during rotation, the face simultaneously morphed into a second face. This procedure should succesfully link frontal

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face views to side views of the same or a different identity, and, according to the temporal contiguity hypothesis, thus enhance viewpoint-invariance in the non-morph condition and/or break invariance in the morph condition.Test phase trials contained two sequential face images – a frontal and a side view. The fMRI experiment also contained trials with untrained faces and same-viewpoint trials. Performance on the same/different task in the behavioral experiment (N=20) was affected by training. There was a significant interaction (p=0.03) between training (linked/not linked) and identity (same/different), reflecting a selective drop in performance for different identity trials of morphed faces. In the fMRI study (N=20), fMRI adaptation effects were found for same-viewpoint images of untrained faces, but no adaptation for untrained faces was present across viewpoints. Only faces which were not morphed during training elicited a slight adaptation across viewpoints in face-selective regions (FFA: p=0.045, OFA: p=0.03, one-tailed t-test). No such effect was present for morphed faces (p=0.55 and p>0.99). Behavioral and neural results are therefore compatible: Temporal contiguity can influence viewpoint tolerance, with more evidence for tolerance when faces are not morphed during training.

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53.4018 Social Judgements Improve Face Recognition More Than Perceptual Judgements

Linoy Schwartz[1](linoy.schwartz@gmail.com), Galit Yovel[1,2]; [1]Sagol School of Neuroscience, Tel-Aviv University, [2]School of Psychological Sciences, Tel-Aviv University

Faces can be typically described both based on their perceptual attributes (e.g. face roundness, symmetry) and social attributes (e.g. how trustworthy is the face?). Which type of these judgements may improve our ability to recognize faces from new views we have not seen before? In a series of studies subjects learned unfamiliar frontal faces while making social, perceptual or no-judgments. We hypothesized that social judgments would generate a more abstract, view-invariant representation than perceptual judgements. During test subjects were presented with four face views from profile to frontal. Results show that social judgements improved recognition as compared to perceptual or no judgments, whereas perceptual judgements did not improve face recognition relative to no judgements. The benefit of socially-judged faces that were learned from frontal view was most prominent in three-quarter view of the same person but did not extend to profile view, which yielded low recognition rates in all conditions. In a follow-up study, faces were learned from frontal and ¾ views in study and were tested from the same and new views. Results show that presenting faces from multiple views did not improve recognition relative to single view presentation for both social and perceptual judgements. Finally, the benefit of social judgements over no judgements was not found for faces of other races, suggesting that the benefit of social judgments may be influenced by the social experience that we have with faces from our own race. Overall, our findings interestingly show that attending to social rather than perceptual aspects of faces may generate an abstract representation of the identity of the face, which particularly benefit face recognition from nearby views that we have not seen before.

53.4019 Comparing word and face recognition: an insoluble conundrum

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The relationship between face recognition and visual word recognition/reading has received increasing attention lately. A core question is whether face and word recognition rely on cognitive and cerebral processes that are largely independent, or rather processes that are distributed and highly shared. This question has been investigated using experimental, neuropsychological, and neuroimaging methods in both healthy and clinical groups. Finding comparable tests of face and word processing is not as straightforward as might be expected. Typically, a test of object processing is also included, as a control, which makes designing experiments all the more challenging. Three main strategies have been used to overcome this problem, each of which has limitations: 1) Compare performances on typical tests of the three stimulus types (e.g., a Face Memory Test, an Object recognition test, and a test of reading out loud); 2) Compare typical effects found in normal participants or clinical groups with the different categories of stimuli (e.g., the face inversion effect and the word length effect) 3) Test the three stimulus categories in the same experimental setup (e.g., delayed matching tasks). None of these methods, however, has provided measurements that enable direct comparison of performances across categories. We propose a simple framework for classifying tests of face, object, and word recognition according to the level of perceptual processing required to perform each test. Using this framework to classify tests and experiments aiming to compare processing across these categories, it becomes apparent that core differences in characteristics (visual and semantic) between the stimuli make the problem of designing comparable tests an insoluble conundrum. By analyzing the experimental paradigms, we might be contributing to our understanding of the differences between word and face processing. The suggested framework may help researchers in creating the least inappropriate experimental designs to test their hypotheses.

53.4020 Comparing human and deep convolutional neural network face-matching performance on disguised face images

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People perform poorly on face-matching tasks that involve unfamiliar identities. Disguise further impairs performance, even for familiar identities, which are usually recognized robustly across image variation (Noyes & Jenkins, 2016). Face recognition algorithms based on deep learning and convolutional neural networks (DCNNs) now perform surprisingly well across image variation, but have not been tested with disguised faces. Here we directly compare DCNN accuracy with human accuracy (Noyes, 2016) for identifying disguised and un-disguised faces. Using the features from the top-level "compact layer" of a recent DCNN (Chen, 2016), we generated representations for un-disguised and disguised images of the same faces from the FAÇADE database (Noyes, 2016). To determine whether images would cluster by their true identity, hierarchical agglomerative clustering was applied to the DCNN face representations. This clustering was compared to human identity-matching performance for the same images. Humans and the DCNN were similarly impaired by disguise when the comparison images were of the same identity (disguise involved evading identity). For different-identity trials, human performance dropped with disguise, but the DCNN performed at the same level on un-disguised and disguised (impersonation) comparisons. Next, we compared performance for only disguised images. DCNN accuracy was surprisingly similar to that of humans for evasion faces - with machine accuracy of 61.54% and average human accuracy of 60.38%. For impersonation of a similar looking person, machine accuracy was 84.62% and human accuracy was 82.18%. However, machines performed more accurately than humans (96.15% > 89.62%) at matching faces disguised to impersonate a very different looking individual. Notably, familiar viewers from Noyes (2016) far outperformed machines and unfamiliar viewers on disguised faces. These findings provide insight into the current performance level of DCNNs in comparison to humans for identifying disguised and undisguised faces.

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53.4021 Does social collaboration benefit face-matching accuracy over simply fusing individuals' responses?

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In face-based identity matching tasks, participants are shown to achieve higher performance when working in collaborative pairs than when working alone (Dowsett & Burton, 2015). However, identity-matching performance is also better when the responses of multiple participants are averaged (i.e., fused) on each item (White et al., 2013; White et al., 2015). Here we asked whether social collaboration adds power to the benefits of simple response averaging. In a challenging unfamiliar face-matching test, we compared individuals (n=68) and social dyads (n=34). Each participant performed the task once as an individual, and once as a member of a dyad, using different subsets of stimuli for each condition. The stimuli consisted of 84 pairs of frontal view face images (42 same-identity; 42 different-identity), varying in illumination and expression. Participants or dyads judged whether each face-pair depicted the same identity or two different identities, responding on a 5-point scale (1: sure same; 5:sure different). Performance was measured as area under the ROC (aROC). Accuracy was higher for social dyads (Mean aROC=0.88) than for individuals (Mean aROC=0.84), [F(1,100) = 5.78, p= .018], replicating Dowsett and Burton (2015). Next, to

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compare social collaboration to simple averaging, a "blind fusion" condition was formed by averaging the responses of pairs of participants within each social dyad on each stimulus. The accuracy obtained through the blind fusion condition (Mean aROC=0.91) was marginally greater than social dyad (Mean aROC=.88), [F(1,66)=4.13, p=.05]. Consistent with the literature, performance was also greater for blind fusion (Mean aROC=0.91), than for individuals (Mean aROC=0.84), [F(1,100)=18.14, p< .0001]. These findings suggest that the wisdom-of-crowds phenomenon observed in unfamiliar face-matching performance does not depend predominantly on the social aspect of dyad collaboration.

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53.4022 Impact of myopia on visual attention and the potential link with cultural differences in visual perception

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Easterners and Westerners have been shown to differ in many visual perceptual tasks, and evidence supports a broader allocation of attention among Easterners than Westerners. For instance, Easterners have a larger global advantage than Westerners in a Navon Task (McKone et al., 2010); they fixate less the eyes and mouth, and more the centre of the face during its processing (Blais et al., 2008); they also tend to process faces in lower spatial frequencies (Tardif et al., in press). Although it has been proposed that perceptual differences emerge from the cultural values (individualistic vs. collectivistic) assumed by each culture (Nisbett et al., 2001), a recent study didn't succeed at finding links between those cultural values and the eye fixation pattern during face processing (Ramon et al., VSS2016). In this study we explored another lower-level hypothesis that could explain the perceptual differences observed between Easterners and Westerners: the impact of myopia on visual attention. Recent evidence suggests that myopes are less affected by crowding in peripheral vision (Caroll et al., VSS2016). Since myopia prevalence is higher among Chinese compared to Caucasians individuals (Lam et al., 2012), this could potentially explain the visual perception differences observed between Easterners and Westerners. The ability to detect global versus local target letters was measured with myopes (N=12) and emmetropes (N=17) using Navon's paradigm. No global/local bias differences were found between the groups [t(28)=1.08, p=0.29]. These results do not support the hypothesis that the difference in the prevalence of myopia between both groups underlies the higher global advantage observed in Easterners. More studies will allow us to verify if myopia can explain the cultural differences observed in fixation patterns and spatial frequency utilization during face perception.

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53.4023 Rhesus monkeys are able to discriminate facial identity and expression

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Faces carry multiple signals: some are stable across time, such as an individual's identity, whereas others are subject to change, such as expression. These stable and changeable attributes appear to have opposing computational demands. A mechanism for discriminating identity would need to distill information that remains constant in a face, whereas a mechanism for discriminating expression would need to be sensitive to change. Although this intuition aligns with most neural models for face perception, it is still a matter of intense debate. The main goal of our research is to determine the extent to which the signals conveyed by facial identity and expression are processed by independent mechanisms. To begin addressing this question, we designed an experiment to determine whether rhesus monkeys (Macaca mulatta) can extract both identity and expression cues from face stimuli. Using a two-alternative force-choice delayed match-to-sample task, we tested four subjects across two task conditions. The stimuli in both conditions were identical, the only difference was whether the task was to match identity or expression. We found that subjects were able to successfully select expression more often than identity on expression discrimination trials, and to select identity more often than expression on identity trials. These results provide the first clear indication that monkeys are able to extract multiple signals from faces.

53.4024 Social dominance orientation influences the perception of facial expressions

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In face-to-face communications, facial expressions provide strong clues for the perception of the social dominance orientation (SDO) of other individuals. Here, we show that, interestingly, processing of facial expressions is different for classified high-dominance (HD) and low-dominance (LD) people. We determined the observers' SDO by applying the dominance subscale questionnaire (Jackson, 1984), and split them up into an HD and an LD group based on their scores. First, we found that, in a challenging face discrimination task between angry and neutral faces, HD participants had significantly shorter reaction times than LD participants, while achieving similar classification accuracies. Further, scalp EEG recordings showed that, when responding to faces in the angry/neutral condition, HD participants had significantly higher P2 amplitudes than LD participants. EEG source imaging indicated that these differences measured at the scalp level emerged from increased bilateral activation of the middle temporal gyri, left superior temporal gyrus, and the cingulate gyrus. While the middle temporal gyri are related to processing of faces, the left superior temporal gyrus is involved in the perception of emotional stimuli and the cingulate gyrus is influential in linking behavioral outcomes to motivation. We suggest that, when confronted with ambiguous/difficult social contexts, HD individuals tend to recruit emotional face processing areas of the brain more strongly than their LD peers, which allows HD individuals to make faster decisions about their social environment.

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53.4025 Encoding and recognition of faces involve different eye-movement dynamics

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Previous incidental evidence suggests that eye movement dynamics differ between the encoding and recognition of faces; however, restricted stimulus presentation time during recognition was a potential confound. The present study aims to distinguish the influences of experimental phase (encoding/recognition) and stimulus presentation time (short/long) on eye movements during facial perception. Participants completed an encoding ("study") phase and a subsequent recognition ("test") phase, with each phase divided into separate blocks of either one- or five-second stimulus presentation time conditions. For our participants, the second fixation was longer in duration during the test than the study phase, regardless of presentation time condition or whether a face had been previously studied. Also, relative fixation density was greater over the eye region during the study phase and greater over lower facial regions during the test phase. The fine-grained patterns of differential fixation density suggest, though, that phase interacted to some degree with the presentation time condition. Importantly, only the long study phase presentation time condition improved recognition, suggesting that facial feature information is integrated over many fixations during encoding, whereas a face identity representation formed through such integration can be rapidly and holistically activated with a small number of fixations during recognition. Our results challenge the scan path replay hypothesis, which has been a prominent hypothesis regarding general visual recognition. While a small number of prior research studies have attempted to challenge the scan path replay hypothesis, the novel theoretical contribution of our study is that it also provides a differential account of face encoding (slower and more integrative) vs. recognition (faster and more holistic). Insofar as face encoding and recognition may be a representative case of visual encoding and recognition more generally, our study may perhaps be a first step in uncovering more general visual perceptual mechanisms.

53.4026 **The effects of multi-modal sources of person information on the face encoding stage.**
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People can be recognized by a number of cues in different modalities, including face, body, voice, name, and biographic information. These are often present in conjunction in daily life. A number of studies have shown cross-modal interactions between these information sources during the retrieval stage of recognition tasks. However, it is less known whether there are cross-modal influences during the encoding stage. Our goal was to determine if either face familiarity or face identification were affected by simultaneous presentation of voice or biographical data when subjects were learning new faces. Using a between-subject design, four groups of 10 participants each learned 24 faces seen in dynamic video-clips with their names written on the screen. 12 of these face/names were presented with other information simultaneously and 12 without. The nature of the other information differed between the four groups. The first group heard the voice of the person stating non-biographic information. The second group heard an announcer giving biographic information for each person. The third group heard the voice of the person stating their own biographic information. A fourth group, a control, heard the announcer stating non-biographic information. In the retrieval phase, subjects saw dynamic faces only, and completed a face familiarity task and an identification (face-to-name matching) task. We found that no condition with additional information gave better or faster accuracy during retrieval than learning the face alone, and that this was true for both familiarity and identification tasks. We conclude that, unlike the retrieval stage, the encoding stage in face memory tasks is relatively immune to cross-modal influences from simultaneous voice or biographical information.

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53.4027 **Network level taxonomy of the core/extended person perception system**
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Previous research has identified a network of cortical areas reliably engaged when perceiving and thinking about other people – the so-called core and extended face-perception systems. These regions have been extensively studied over the past two decades but a systematic study of the dynamical changes of this system across varied tasks has been lacking. Here, in a block design fMRI experiment, healthy volunteers (N=20) were presented with highly familiar faces and asked to recall person-specific semantic information (roughly grouped into nominal, physical, social, episodic and factual information - 10 experimental conditions total). Response profiles were collected from independently localised face selective brain regions. Examining cognitive activation in context permitted a fuller understanding of regional contribution. For instance, while the ATL is engaged in nominal knowledge compared to control, relative to the other cognitive domains ATL is comparatively deactivated, in contradistinction to previous findings. Rather the ATL shows tuning for social cognition. Instead the IFG was weighted more more strongly towards nominal tasks. By applying network-level Representational Similarity Analysis (netRSA) we identified three collections of regions with the biggest pattern similarity, forming three distinct functional sub-units: 1) Precuneus, mPFC, pSTSs and ATLs. 2): Occipital and fusiform face areas together with orbital and inferior-frontal gyri, 3) Anterior face patches and the amygdalae [validated via bootstrapping]. Examining brain responses in context of a range of tasks enables fuller inferences to be made about regional tuning. Furthermore, netRSA reveals systems-level organization into functional processing units that coordinate to address different task demands. Core regions form transient functional relationships with frontal regions possibly reflecting top-down control. Regions associated with default mode preserve their relationship during task and jointly support episodic, semantic and social person-related cognition but physical and nominal cognition to a much lesser extent.

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53.4028 **Modeling face-type and threat: Biased decision making in expression interpretation**
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Prior research indicates stereotypical Black faces (e.g., wide nose, full lips) are often associated with crime and violence (Kleider, Cavrak, & Knuycky, 2012). In the current study, we investigated whether a stereotypical face may bias the interpretation of facial expression. Specifically, would stereotypical faces be judged as threatening? Faces were pre-rated in a separate study for level of stereotypicality and expression, and then divided into four categories: stereotypicality (high, low) and expression (neutral, threatening). We applied decision-bound theoretic analysis to explore perceptual and decisional interactions between the two dimensions. We found evidence for integration of perceptual dimensions. Stereotypical faces tended to be seen as more threatening than non-stereotypical faces. This was true for images depicting a neutral expression as well as for images displaying a threatening expression. This pattern held across participant gender and ethnicity. Overall results suggest that stereotypical faces are interpreted as threatening relative to non-stereotypical faces.

53.4029 **Connecting Holistic Processing with Brain Regions Selective for Face Processing and Face Memory: A Regression Approach**
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Holistic processing (HP) is widely believed to play a critical role in face processing and recognition, and a variety of tasks have been created to gauge the respective contribution of HP and non-HP (analytic) in faces. However, there has been some controversy regarding the role of HP in face memory with respect to individual differences. One possible reason for the controversy may have to with the different approaches used to measuring HP. In the present study, we first compared the subtraction and regression approaches to measuring HP in three standard face-processing tasks (component, configural, and composite), and found that, compared to subtraction, residues after regressing the non-HP element from each face processing task can provide purer measures of HP. Moreover, the HP estimate of the component task can best predict performance on the Taiwanese Face Memory Test (TMFT). We next investigated whether neural activity in the face-selective brain regions, including fusiform face area (FFA), occipital face area (OFA), posterior region of superior temporal sulcus (pSTS), and ventral anterior temporal lobes (vATLs), can effectively predict HP performance on the three face processing tasks. To that end, we first identified during the functional scan those regions by asking participants to perform a one-back task, while viewing either static images or dynamic videos. We then determined for each region of interest the cluster size associated with maximum face selectivity. Finally, correlation analyses revealed that participants with greater BOLD signals in FFA and vATL demonstrated better performance on the HP of face processing tasks. Taken together, our findings indicate that (a) the regression approach can provide more robust measures of HP, (b) HP of the component task can best predict performance on face memory, and most importantly (c) connections between regression-based measures of HP with brain regions selective for face processing and face memory.

Acknowledgement: Ministry of Science and Technology, Taiwan, ROC

53.4030 **Testing the Robustness of Newly Acquired Face Memory: An fMRI Study**
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Numerous faces are encountered on daily basis. While some remain novel, others may hold the propensity of becoming familiar. In a series of studies, we have shown that multiple exposures coupled with sufficient variation in expression and pose can help transform the identity of a novel face into a perceptually familiar one (Shyi & He, 2011; Shyi & Lin, 2014; Cheng & Shyi, 2014). However, the mechanisms for transforming a changeable aspect (e.g., expression) of a face into invariant features for identity is not clear. Moreover the robustness of these newly acquired face memory is also unknown. We addressed these questions by first training participants to learn a set of novel faces via the combination of multiple exposures with variations in expression. Their recognition memory for the newly learned faces were then tested twice consecutively while functional scanning of their brains was carried out. Behavioral results shown that the accuracy for both the original and generalized images decreased from the first to the second test, while the false alarm for distractor images maintained at the same level, suggesting that the memory strength for both original and generalized images decayed between the two recognition tests. Brain imaging results on the other hand showed that the extent of memory decay for the original images was positively correlated with the decrement of brain activity in both the bilateral posterior and middle region of superior temporal sulcus (STS). In contrast, the memory decay for the generalized images exhibited no such correlations. These findings suggest that (a) as a region selective for processing changeable aspect of faces, STS can help create invariant features for identity to support recognition memory, and (b) the neural basis underlying generalized face images differs from those underneath the original images.

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Face Perception: Wholes, parts, and features

Tuesday, May 23, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.4031 Viewing faces through apertures

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Faces are notoriously hard to perceive when turned upside-down. It is often claimed that perceptual decrements reflect a switch from whole-face processing, to a serial analysis of individual features. To test this view, we examined observers' ability to categorise faces briefly presented in their entirety, or viewed through a dynamic aperture that moved incrementally across the facial image. By exposing faces region-by-region, aperture viewing forces observers to use serial feature processing, similar to that supposedly recruited by inverted faces. Consistent with holistic processing accounts, facial identity, gender, and age were categorised more precisely when upright faces were viewed in their entirety, than when viewed through the aperture. Crucially, however, we also observed aperture effects (i.e., greater decision noise) for inverted faces equal to, or greater than, those seen for upright faces (Experiment 1). We go on to show that this pattern is seen irrespective of the direction of aperture transition (Experiment 2) or the nature of the fill used to replace the occluded regions of the to-be-judged image (Experiment 3). A similar pattern is also seen when observers categorise facial expressions (Experiment 4). Finally, we consider the utility of the paradigm for studying individual differences in holistic processing. We present data from fourteen individuals with developmental prosopagnosia that suggest striking variability in the use of whole-face cues in this population (Experiment 5). These results suggest that when interpreting inverted faces, access to the wider face context is far more important than currently believed. Where inversion results in poor local descriptions, possibly due to violation of lighting priors, residual ability to integrate information from contiguous regions may be crucial.

53.4032 Holistic processing of faces is modulated by facial expressions

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Faces are thought to be processed holistically: all facial features appear to be processed as a whole, instead of as individual features. At a glance, observers can easily extract the identity and emotional expressions of a face. To what extent is identity and expression processing integrated? Previous findings often used only neutral faces to study holistic processing of facial identity, thus, it remains unclear to what extent facial expressions may influence identification judgments. Moreover, observers appear to emphasize different facial features in recognizing various facial expressions, such as processing both the top and bottom face halves for happy faces, and focusing on the top halves for angry faces. Here we asked whether holistic processing of facial identity is modulated by happy or angry facial expressions. In a composite paradigm, participants (N=29) performed identity matching on either the top or bottom halves of each pair of sequentially presented composites, and were asked to ignore the task-irrelevant halves. The face halves were either aligned or misaligned. The pairing of identities between the face halves were either congruent or incongruent. The composites showed happy, angry, or neutral expressions; the expressions on the top and bottom halves of the composites were always congruent, and the expression conditions were randomized. We found significant holistic processing in all expression conditions. More importantly, the holistic effects were modulated by expressions, as indicated by a significant 3-way interaction of expression, alignment, and congruency. Critically, holistic processing was stronger for happy than angry faces. No significant difference in the magnitude of holistic processing was found in other comparisons. The results suggest that identity judgement is influenced by the different processing strategies for different expressions, even when emotional information is task-irrelevant. This provides evidence that holistic processing integrate the identity and emotional information of faces, and is dynamic across trials.

53.4033 Holistic and Analytic Processing of Identity and Expression in Faces: A Systems Factorial Technology Approach

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It is widely believed that face identity is achieved via holistic processing of the representation integrated over parts of a face. In contrast, processing of facial expressions can be undertaken via analytic processing based on representation of separate parts. The composite face task (CFT) is a commonly used paradigm to investigate the underlying mechanism of face processing. In the most diagnostic condition of CFT, two identical top halves joined by two different bottom halves are difficult to judge whether or not they are identical when the top and bottom halves are aligned than when they are misaligned. Such failure of selective attention has been construed as evidence of holistic processing for processing both face identity and facial expression. However, using the CFT, some recent studies have argued that both identity and expression are processed analytically. Hence, whether identity and expression of a face requires analytic or holistic processing remains controversial. To resolve the controversy, the present study combined the redundant target design and the CFT within the framework of systems factorial technology (SFT) and investigated the nature of capacity coefficients for processing identity and expression. In Experiments 1 and 2, participants were asked to employ either the self-terminating rule or the exhaustive stopping rule for discriminating face identities. In Experiment 3 and 4, they were asked to adopt the two stopping rules for discriminating facial expressions, respectively. Results of Experiments 1 and 3 revealed that a majority of participants exhibited unlimited or limited capacity, which is consistent with analytic processing. In contrast, results of Experiments 2 and 4 revealed super capacity for most participants, which is consistent with holistic processing. Taken together, these findings suggest that the face identity and facial expression can be processed either holistically or analytically depending upon the use of specific stopping strategy.

53.4034 Is holistic processing ensemble coding?

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Research has shown that people perceive facial expressions of a single face holistically (holistic processing) and can statistically summarize facial expressions in a crowd (ensemble coding). Previously, we tested if the two kinds of processing relied on the same mechanisms (Sun & Chong, 2016). We utilized the face inversion effect to disrupt emotion judgments of a single and multiple faces, and found that the face inversion effect was weaker with multiple faces than a single face, suggesting that the holistic processing of individual faces and the ensemble coding of multiple faces are rooted in different mechanisms. We hypothesized that interferences generated by the inversion could have differed in assessing emotions of a

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single and multiple faces. As the mouth carries more information than the eyes in a happiness judgment (Calvo et al., 2014), facial features (the left and right eyes, nose, and mouth), unlike individual faces in a crowd, could have unevenly contributed to the judgments of specific emotions. Thus, we varied the number of inverted features in single-face judgments and that of inverted faces in multiple-face judgments. Specifically, four features within a face or four faces shown in one side from fixation could be all upright, all inverted, or two upright and two inverted. Participants judged the emotional intensity of a single face or the average intensity of the four faces compared to a single face shown on the other side. Results showed that the intensity discrimination became poor as more inverted features and faces were shown. Moreover, whereas happy judgments with a single face were disrupted mostly by the mouth inversion, the average intensity judgments were equally influenced by all faces regardless of their orientation. These results suggest that the different inversion effects arose from differential contributions of components to the perception of single or mean facial expression.

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53.4035 **The role of the upper and lower face in the recognition of facial identity in dynamic stimuli.**

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Background: Studies show that the information from the upper half of a face plays a greater role in the recognition of facial identity than the lower half. However, in daily life faces are usually encountered as dynamic stimuli, and recent research has shown that dynamic signatures in facial motion contribute to face recognition. Given that the lower half of the face has more mobile structures, this raises the question whether the upper face advantage is also present with dynamic faces. Objective: Our goal was to determine the relative contribution of the upper and lower face in a short-term face familiarity task. Methods: During the encoding phase, 30 subjects learned 12 whole faces, six as static images and six as dynamic video-clips. During the retrieval phase, subjects saw upper or lower halves and reported which of 3 stimuli belonged to one of the learned set. Half of the subjects saw static images and half saw video-clips in the retrieval phase.. Results: There was an interaction between image type at encoding and retrieval, with 10% better recognition when faces were learned from dynamic video-clips than from static images, but only when tested with dynamic stimuli. Regardless of the type of learning, testing with static images showed a small 3% advantage for the upper face, whereas testing with dynamic images had a .3% advantage for the lower face, but these differences were too small to be significant or to generate an interaction involving face halves. Conclusion: Dynamic presentation of faces enhance encoding of identity, but the influence of face-half at retrieval is modest or non-existent.

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53.4036 **The clone devaluation effect: Many exactly same faces induce eerie impressions**

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It is highly unusual that individuals with exactly the same face are together in the same place. What impression is formed by them? It is important issue to consider people's psychological reactions to the individuals and objects with the same face such clone humans and humanoid robots when the mass production of them become possible in the future. We made two hypotheses about this issue. One is that individuals with exactly the same face would be positively evaluated because a previous study revealed that processing fluency was associated with positive evaluation (Reber, Winkielman, & Schwarz, 1998). Another is that they would be negatively evaluated because objects which have features with realism inconsistency are associated with negative evaluation (MacDorman and Chattopadhyay, 2016). To test these hypotheses, the present study investigated what impressions were formed when people observed a scene in which six individuals with exactly the same face exist. 121 Japanese people were participated in the experiment online. We made three kinds of stimuli pictures; pictures of six individuals with the same face (clone condition), pictures of an individual (single condition), and pictures of six individuals with faces different from each other (non-clone condition). Participants evaluated the impression (eeriness, valence, and realism) of the pictures on a 7-point Likert-scale. The results showed that the pictures in the clone condition were significantly highly eerie, realistic, and negative compared to the pictures in the other conditions. Therefore, it is suggested that individuals with the same face induced negative impressions. This is a new devaluation effect—the clone devaluation effect.

53.4037 **Measuring susceptibility to the composite face effect using psychophysics**

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The top half of one face appears to fuse perceptually with the bottom half of another, when aligned spatially and presented upright. While this composite face illusion (CFI) is easy to demonstrate, there is considerable disagreement about how best to measure observers' susceptibility. Prevailing matching approaches require observers to discriminate target regions in pairs of composite faces. However, findings differ depending on the authors' choice of design ('standard' or 'complete') and their approach to analysis. Here we present a novel CFI paradigm based on psychophysical approaches to the measurement of illusion susceptibility. Observers made binary judgements about target regions ('male' or 'female'; 'child' or 'adult'). Target regions were drawn from morph continua, either blending a male and a female face, or a boy's and a man's face. In the gender variant, distractor regions were unambiguously male or female; in the age variant, the distractor regions were unambiguously child-like or adult-like. In this procedure, susceptibility to the CFI biases observers' classification performance; for example, observers are more likely to classify targets as male or female in the presence of aligned male and female distractors, respectively. Susceptibility to the CFI is inferred from the degree to which an individual's psychometric function shifts in the two conditions. When aligned with targets, distractor regions induced substantial shifts in both the gender and age variants. As expected, misaligned distractors and inverted arrangements yielded little or no shift. Function shifts for age and gender were correlated in 67 typical observers suggestive of a common binding process. However, shifts failed to correlate with face recognition ability measured using the Cambridge Face Memory Test. Moreover, 16 developmental prosopagnosics showed typical shifts when tested on the gender variant. Taken together, these findings challenge the view that susceptibility to the CFI is closely related to face recognition ability.

53.4038 **Morphing Angelina into Jessica reveals identity specific spatial frequency tuning for faces**

Gabrielle Dugas[1,2](dugg06@uqo.ca), Charbonneau Isabelle[1,2], Royer Jessica[1,2], Blais Caroline[1,2], Brisson Benoit[3], Fiset Daniel[1,2]; [1]Université du Québec en Outaouais, [2]Centre de Recherche en Neuropsychologie et Cognition, [3]Université du Québec en Outaouais

Many studies have investigated the role of spatial frequencies (SF) in face processing. However, the majority have used tasks where it is difficult to dissociate the impact of physical and identity-specific information. To investigate this question, we first asked 20 participants to classify stimuli taken from 40 morph continua between pairs of famous actors. Sixteen continua reached our categorical perception criteria, i.e. the stimulus at □ along the morph continuum was reliably identified as the first identity whereas the stimulus at □ was reliably identified as the second identity. In the second part of the study, seven participants performed a match-to-sample task where the response stimuli (1248 trials per condition) were sampled with SF Bubbles (Willenbockel et al., 2010). On each trial, the participants saw a target (either the □-□ or the □-□ of a given continuum) and two response alternatives, both sampled with the same Bubbles. One response choice was visually identical to the sample (i.e. the correct response) whereas the other was taken either from the same perceived identity (e.g. 1-0 for the □-□; within-identity trial [WIT]) or from different identities (e.g. □-□ for the □-□; between-identity trial [BIT]). Expectedly, WIT trials were more difficult than BIT trials for all participants. Multiple regression analyses on

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the sampled SFs and the participants' reaction times (using a median split) were used to create classification images for WIT and BIT trials separately. Comparing diagnostic SFs for these two conditions reveals identity-specific SF tuning for faces. This comparison reveals a spatial frequency band between 4.9 and 8.1 cpf (Zcrit=3.45, p< 0.025; peaking at 5.6 cpf) that is specifically dedicated for identifying known faces. These data offer interesting insight about the visual granularity at which identity is represented in memory.

Acknowledgement: NSERC

53.4039 The Effects of Familiarity and Orientation when Correcting Spatially Distorted Faces Nick Donnelly[1](nd5@soton.ac.uk), Natalie Mestry[1]; [1]Department of Psychology, University of Southampton

Sandford and Burton (2014) asked participants to rescale faces to normal after being initially presented with faces of distorted proportions. The important and surprising result was that participants were better at normalising unfamiliar faces compared to familiar faces. They suggested this was due to an increased tolerance to distortion with familiar faces: a result interpreted as questioning the role of relational information in familiar face recognition. We repeated their study in two experiments. In both experiments participants first rated our set of faces for familiarity on a 7-point scale. For each participant, only faces rated as very familiar (7) or not familiar at all (1) were included in analysis, though all participants viewed all faces in rating and normalising tasks. In addition to manipulating familiarity (familiar or unfamiliar), orientation (upright versus inverted) was also manipulated. Experiments 1 and 2 showed an effect of orientation on normalising error with upright faces normalised more accurately than inverted faces. Neither Experiment 1 nor 2 showed the previous influence of familiarity in normalising error. Experiment 1 actually showed familiar faces to be normalised more accurately than unfamiliar faces, in contrast to the result of Sandford and Burton. In Experiment 2, participants also completed the Cambridge Face Matching Task (CFMT: Duchaine & Nakayama, 2006) and Cambridge Face Perception Task (Duchaine, Germine & Nakayama, 2007). Correlating test performance with error in normalising faces showed a relationship between performance in the Cambridge Face Matching Task and normalising faces. Better face memory was associated with more accurate normalisation for familiar and unfamiliar, upright and inverted faces. We consider the effect of orientation and the failure of our two experiments to replicate the Sandford and Burton finding, alongside the correlation with performance on the CFMT. We suggest a likely mechanism underpinning the ability to normalise familiar and unfamiliar faces.

53.4040 A Preference for Flipped Depictions of Self Malerie McDowell[1](mcdmg-17@rhodes.edu), Jordan Suchow[2], Jason Haberman[1]; [1]Department of Psychology, Rhodes College, [2]Institute of Cognitive and Brain Sciences, UC Berkeley

Because the eyes point outward, visual experience of our own face is mediated by depictions and reflections, which are unlike what others see — a mirror reflects the image, and a depiction transforms it. Does this altered experience affect perceptions and judgments about our appearance? Here, we asked observers (N = 18) to view their likeness in photographs that were flipped (as when viewed in a mirror) or not flipped (as when viewed in a depiction). Observers also adapted (or not) to the flipped or unflipped photographs in a 2 × 2 design: 1) flipped; 2) unflipped; 3) adapt to flipped for 60 seconds then view unflipped image; 4) adapt to unflipped image for 60 seconds then view the flipped image. Photographs of each observer were taken before the experiment. Observers rated (on a scale of 1-7) how much each image looked like them and how much they liked the image. Each observer was run in each condition three times in random order. One-way repeated-measures ANOVAs revealed a significant preference for the flipped image (as in a mirror) compared to the unflipped image (as in a depiction) for both questions. This effect was exaggerated for the condition in which observers first adapted to the unflipped image before viewing the flipped image. These results are likely driven by a strong, albeit malleable, representation of self, one created by most commonly viewing ourselves in a mirror, with unflipped images being perceived more 'unlike' one's self and less pleasant than a flipped image because it exposes asymmetries with which the viewer is unfamiliar.

53.4041 Discovering the critical features of face recognition Galit Yovel[1](gality@post.tau.ac.il), Naphtali Abudarham[1]; [1]School of Psychological Sciences, Tel Aviv University

A fundamental aim in the quest to understand face recognition is to reveal which features determine the identity of a face. Previously, we discovered a subset of facial features that determine the degree of perceptual similarity between unfamiliar faces. We did that by constructing a multi-dimensional facial-feature space, and correlated face space distances, based on rating of each feature, with perceptual similarity judgements. We found that features for which subjects have high perceptual sensitivity (high-PS), including the hair, the eyes - shape and color, eyebrow thickness, and lip-thickness, were strongly correlated with face similarity judgements. In contrast, features for which subjects have low perceptual sensitivity (low-PS), including face-proportion, eye-distance or skin-color, did not affect face similarity judgements. To determine whether these features are critical for face recognition, in the current study we replaced these features in familiar faces and asked subjects if they recognize the modified face. In particular, we examined recognition as a function of the type of change, high or low-PS features, and the number of features that were changed. Subjects were either presented with low or high-PS changes and first saw faces that underwent maximal number of changes followed by faces that underwent smaller number of changes. Our findings show that changing five low-PS features had little influence on face recognition, and was similar to the effect of changing only one or two high-PS features. Changing four or five high-PS features made the famous face unrecognizable. In contrast, a face recognition software was similarly sensitive to both types of changes. We conclude that human face recognition depends on a subset of features for which we are highly sensitive. These features may be invariant under different views, illuminations or expressions. These findings challenge prevalent claims, which primarily emphasize the role of configural information in face recognition.

53.4042 Factors that do and don't make flashing faces more distorted Hannah Pearson[1](hannah.i.pearson@ndsu.edu), Benjamin Balas[1]; [1]Psychology Department, North Dakota State University

Normal faces rapidly presented in the visual peripher are perceived as grotesque and distorted (Tangen, Murphy, Thompson, 2011). This phenomenon, "The flashed-face distortion effect" (FFD) is a powerful illusion that reveals important properties of how faces are coded in peripheral vision. Presently, we manipulated aspects of facial appearance and spatial/temporal properties of the flashed-face stimulus to determine what factors modulate the illusion's strength. In our first study, we examined how face orientation (upright vs. inverted), makeup, and image size each affected FFD strength. Face inversion was intended as a means of determining the illusion's face-specificity, while varying makeup and image size was intended to reveal how local contrast and spatial scale impacted the FFD. We recruited 28 participants to complete two experimental blocks: One in which makeup and orientation were varied across trials, and another in which makeup and image size (at a fixed eccentricity) were varied. Participants rated apparent distortion using a 1-7 scale. We found that neither the presence of makeup nor face orientation impacted the FFD, but image size did. Specifically, faces presented at an intermediate size (~4 degrees of visual angle) were rated as more distorted than smaller or larger faces (p=0.003). In our second study, we examined how perceived distortion was impacted by makeup and both the eccentricity and duration of the images comprising the FFD sequences. Briefly, we again found no impact of makeup on the FFD, but did find that both longer image durations (p< 0.001) and greater eccentricities (p< 0.001) led to significantly more distortion. These results suggest that the FFD is not a face-specific effect, but instead depends on low-level spatial and temporal factors. The FFD may thus reflect the dynamics of pooling operations in the visual periphery and should be observable with other object classes.

53.4043 Inversion, Configural Recognition, and Part Recognition in Long-Term Memory for Faces Mitchell Meltzer[1](mitchell.meltzer@utdallas.edu), Gowtham Ganesan[1], Michelle Min[1], James Bartlett[1]; [1]The University of Texas at Dallas

Investigating the role of holistic processing in face recognition memory, Meltzer et al. (VSS, 2016) presented participants with a study list followed by a test containing intact (studied) faces, conjunction faces (recombinations of studied face parts), feature faces (containing one old part and one new part), and entirely new faces. In response to each test face, participants made separate recognition judgments for the top and bottom face-halves, and for the face as a whole. Face-half judgments and whole-face judgments produced equivalent levels of intact-conjunction discrimination, suggesting that such discrimination is based on a uni-dimensional familiarity signal as opposed to a flexible recollection process. However, when holistic processing was disrupted by inverting the faces and misaligning their top and bottom halves, whole-face judgments produced higher intact-conjunction discrimination than half-face judgments, suggesting a flexible recollection process that can be controlled to meet to task demands. In support of this conclusion, the conditional probability of recognizing the parts of conjunction faces and feature faces, given their rejection as new whole faces, was low with well-formed faces, and significantly higher with inverted-misaligned faces. Meltzer et al. conjectured that holistic face processing has a "dark side," forcing participants to recognize faces based on global familiarity, preventing flexible recognition of parts as well as wholes. To further test this hypothesis, a new experiment compared performance with upright and inverted-but-well-aligned faces. Based on evidence that inversion alone disrupts holistic processing (McKone et al., 2013), we predicted that the effects of inversion would resemble the effects of inversion and misalignment combined. In fact, this was the case, but the effects were smaller and statistically weak. This might indicate that inversion disrupts but does not eliminate holistic processing, or that familiarity-based responding reflects unitization rather than holistic processing, and that inversion impairs unitization without necessarily eliminating it.

53.4044 Can Familiar Faces be Negatively Detected at RSVP Rates?

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In "negative detection" RSVP tasks, subjects detect whether an object is not a member of a prespecified category, such as "modes of transportation." Although detection accuracy is clearly lower than with basic level detection (e.g., "chair"), it is, nonetheless, well above chance. Could such negative detection be achieved for faces, when the task was to detect an unspecified celebrity's face in a stream of non celebrity faces? Subjects also performed negative detection for the categories of animals, clothes, tools, modes of transportation, and plants. Object and face images, all in color, were taken from a Google Image search. All images were depicted on a homogeneous grey background. The non-celebrity face images were taken from websites featuring colored headshots of aspiring actors and business executives. The celebrities were the top 50 most familiar celebrities, as rated by USC undergraduates, from the USC Face and Voice Celebrity Recognition Tests. In the experimenters' judgment, all the images were of high professional quality with no noticeable difference in quality between the images of celebrities and non-celebrities. Subjects viewed RSVP sequences of 32 images. Targets were present in 50% of the sequences but never in the first six or last six positions. For faces, the images were presented at rates of 114, 132, or 150 msec/image. All the objects were shown at a rate of 76 msec/image. On the basis of diagnostic tests for prosopagnosia, each subject was classified as a developmental prosopagnosic (DP) or a Control. Overall error rates on celebrity face detection was well above chance for Controls and DPs (Supplement Fig. 1), with Contols having a lower error rate. Negative detection of objects was much more accurate and virtually identical for Controls and DPs. There is a face familiarity signal that can be detected at RSVP rates.

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53.4045 Lateralisation and binding of dynamic facial features

Ben Brown[1](ben.brown.13@ucl.ac.uk), Vanessa Enahoro[1], Alan Johnston[1]; [1]School of Psychology, University of Nottingham

Faces transmit a complex stream of social information via coordinated global motion. Their encoding is predominantly right-hemisphere lateralised and entails the binding of features into a holistic representation (Ramon & Rossion, 2011, Brain Cogn., 78, 7-13). Given recent evidence of timing-dependent interactions between moving facial features (Cook et al, 2015, Psychol. Sci., 26, 512-517; Iwasaki & Noguchi, 2016, Sci. Rep., 6, 22049), we asked whether dynamic binding was similarly lateralised. Twenty-two participants viewed pairs of animated facial avatars, whose eyebrows oscillated vertically while their mouths opened and closed. Participants had to detect which face (2IFC) contained misaligned eyebrow movement. Stimuli were presented in either the left or right visual hemifield in alternating trials, and fixation was enforced using an eye tracker. Mouth movement of both faces opposed, trailed, matched or led eyebrow movement (0, 90, 180, or 270 degrees of phase angle) in separate blocks. Stimuli were presented for 3 seconds, either upright or inverted, in separate blocks. Faces subtended 5 DVA (width), with eccentricity 3.125 DVA (fixation to centre) and feature oscillation set to 1.5Hz. Each participant provided 40 trials per condition from which we calculated percentages correct. A 4x2x2 repeated-measures ANOVA showed a significant interaction between hemifield and eyebrow-mouth relative phase ($F(3, 63) = 4.31$, $p = .01$), driving a significant main effect of phase ($F(3, 63) = 4.05$, $p = .01$). Collapsing over synchronous (0° and 180°) and asynchronous (90° and 270°) motion reveals a specific performance reduction for synchronicity in the right hemifield (RH mean correct 58.85% and 63.38%; LH 62.56% and 63.36%). We found no inversion effect however ($F(1,21) = 2.58$, $p = .12$). We can conclude that the left hemisphere appears susceptible to interference by coincident feature motion, which may indicate involvement of left hemisphere mechanisms for the analysis of facial speech.

Acknowledgement: BBSRC

53.4046 Preserved eye sensitivity of the N170 ERP component across face size

Karisa Parkington[1](kparkington@uwaterloo.ca), R. Elif Ermis[1], Roxane Itier[1]; [1]Department of Psychology, University of Waterloo

The N170 is an early face- and eye-sensitive ERP component. Recent gaze-contingent paradigms have demonstrated the N170 sensitivity to eyes even within the context of the whole face, questioning the generally accepted view that this ERP component reflects holistic processing. The present study tested whether this eye sensitivity varied with face size. We compared N170 modulations when facial features (left eye, right eye, nose, and mouth) were fixated within faces of varying sizes. One group of participants viewed large faces (8o, 10o, 12o, and 14o), and a second group of participants viewed small faces (2o, 4o, 6o, and 8o). Featural fixation was enforced using a gaze-contingent eye-tracking procedure. The N170 did not vary with larger face sizes, but was smallest and most delayed for the smallest face size of 2°. Most importantly, an eye sensitivity was observed for all face sizes, with larger and later N170 responses to faces fixated on an eye, compared to nose or mouth fixations, which did not differ. These results highlight the particular sensitivity of the N170 to eye information, and demonstrate that this sensitivity does not depend on face size. In line with recent gaze-contingent ERP studies, these findings support the view that the N170 does not reflect a purely holistic process. Early face perception may instead be reliant on a complex integration of featural and holistic processing mechanisms where eyes play a central role. Implications for theories of face perception will be discussed.

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53.4047 An fMRI half-field repetition suppression study of chimeric faces

Matthew Harrison[1](mt.harrison@gmail.com), Zhiheng Zhou[1], Lars Strother[1]; [1]Department of Psychology, University of Nevada Reno

The fusiform face area (FFA) and occipital face area (OFA) are part of a network of face-selective neural populations in the ventral visual pathway. The FFA is typically associated with "holistic" face processing whereas the OFA is typically associated with the visual processing of face features, although the two presumably work together to achieve whole-face representations. We used an fMRI half-field repetition suppression technique to study the neural representation of hemifield-split chimeric faces. Observers viewed chimeric faces centrally, and the faces either repeated in full, changed in full, changed to the right of midline (RVF change) or changed to the left of midline (LVF change). We observed considerable evidence of repetition suppression when whole faces were repeated, both in bilateral face-selective cortex (FFA; OFA; and face-selective posterior fusiform, pFus), and also in some regions of retinotopic visual cortex. Whole-face repetition suppression was strongest in bilateral OFA and pFus. Of particular interest was the degree to which the OFA, pFus and FFA voxels in each hemisphere showed a contralateral bias for half-face changes. We found that OFA and pFus voxels showed clear contralateral bias for half-face changes, but nevertheless showed substantial "release" from repetition suppression for half-face changes in the ipsilateral visual field. In contrast, the FFA showed equivalent release from repetition suppression for half-face changes (RVF and LVF, no contralateral bias) and whole-faces changes. Whole-brain analysis showed greater overall contralateral bias in the right

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hemisphere as compared to the left, including portions of face-selective cortex. Our findings are consistent with greater receptive fields sizes in the FFA as compared to those in more posterior face-selective areas. Interestingly, our half-field method revealed results that were not observed in previous fMRI studies of contralateral bias for face stimuli in which entire faces were viewed in either the RVF or the LVF.

Object Recognition: Reading

Tuesday, May 23, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.4048 How reading changes letter representations: a double dissociation using orthographically distinct scripts in India

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Reading is a recent cultural invention that exploits the intrinsic recognition capacities of our visual system. But does reading consist only of learning letter-sound mappings, or does it also fundamentally alter letter representations? This question has been difficult to address because (1) illiterates and literates everywhere differ along socioeconomic and cognitive dimensions that confound all comparisons and (2) in the Western world, nearly all languages use nearly the same Latin letters. We addressed this question by exploiting the orthographic diversity of Indian languages. Specifically, we identified two distinct groups of students (both English-literate) but with one group fluent in reading the Telugu script but not the Malayalam script, and the other group fluent in reading Malayalam but not Telugu. To probe letter representations without reading, we used oddball visual search as a natural index of similarity between shapes. In Experiment 1, both groups of readers searched for a Telugu letter among Telugu letters, or a Malayalam letter among Malayalam letters. The main result is a double dissociation: in both groups, searching among familiar letters was more efficient than searching among novel letters. However, letter representations were only subtly altered because search times were strongly correlated across literates and illiterates. In Experiment 2, we asked whether reading alters the relationship between familiar and novel letters. To this end, both groups of subjects performed searches with the target from one script and the distractors were from the other. The main result was again a double dissociation: in both groups, finding an unfamiliar letter was easier among familiar letters than vice-versa. Taken together, our results show that reading alters letter representations through a somewhat paradoxical effect of familiarity: familiar letters are both more discriminable, yet less salient compared to novel letters.

53.4049 The effects of colour and spatial noise on reading performance in human vision

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Background: Coloured lenses and light are used to optimise reading in a several patient groups such as those with reading difficulties, migraine, and low vision. The underlying mechanisms are poorly understood. Northway et al (2010) have shown that coloured lenses reduce the effects of noise in visually symptomatic readers. Purpose: To evaluate how reading speed and accuracy are affected by variations in spectral wavelength and noise. Methods: Ten participants (18-45 years) read under three different colours of light to align with L cone, M cone and S cone function using spectrally controlled LED lights under controlled levels of luminance (30 lux). Normal English words with 0, 0.3and 0.6 spatial noise created by displacement of the letters were read aloud for 1 minute and recorded. The average number of words read was calculated under each of the conditions and statistical analysis was carried out. Results: Reading speed was not significantly affected by colour (Anova $p=0.25$). The introduction of noise significantly reduced reading speed (Anova $p< 0.0001$). As noise increased reading speed reduced further however reading speed in blue light (S cone) was least affected by noise and was significantly better in short wavelength light when compared with reading speed under long or medium wavelengths when noise is present. (Anova, Tukey correction $P< 0.0001$). Conclusion: Reading speed does not seem to be affected by colour directly. Spatial noise does however reduce reading speed but this effect is least when short wavelength light is used. Those who complain of visual symptoms when reading may be more adversely affected by noise and as such these results would suggest that blue light or filters would be the maximal colour to reduce the effects of noise when reading.

Acknowledgement: Optometry Depertment, College of Applied Medical Sciences, Qassim University

53.4050 Different reading tasks measure different reading behaviors.

Tiffany Arango[1](arango.t@husky.neu.edu), Fang Hou[3], Luis Lesmes[5], Deyue Yu[4], Zhong-Lu Lin[2], Peter Bex[1]; [1]Psychology, Northeastern University, Boston, MA, USA, [2]Psychology, Ohio State University, Columbus, OH, USA, [3]Wenzhou Medical University, Wenzhou, Zhejiang, China, [4]Optometry, Ohio State University, Columbus, OH, USA, [5]Adaptive Sensory Technology Inc, San Diego, CA, USA

Reading is a primary problem for low vision patients and a functional endpoint for eye disease. However, there is limited agreement on reading assessment methods for clinical outcomes. Many clinical reading tests lack standardized materials for repeated testing and cannot be self-administered, which limit their use for vision rehabilitation and home assessment. We compared three different reading measurements that attempt to address these limitations. Normally-sighted participants (N=13) completed a MNREAD test (Legge et al.,1993), and two different 2AFC reading tasks in counterbalanced order. In one 2AFC task, participants identified whether 5-letter pentagrams, syntactically matched to English, were words or non-words. In the other 2AFC task, participants indicated whether four-word sentences were logically true or false (Crossland et al., 2008). The font size and exposure duration was controlled by a quick Reading algorithm (Lu et al., 2016) that maximized the expected information gain from each trial and updated the posterior distribution of the parameters of the reading function. All lexical stimuli were presented on a computer monitor as black letters on a white background and 2AFC stimuli were pre and post masked with a sequence of Xs. The data from each experiment were fit by an exponential function with parameters for reading acuity (logMAR), acuity reserve and maximum reading speed (words per minute). In all cases, reading speed increased quickly as an exponential function of letter size, in line with previous studies. However, the parameters for the word/non-word, true/false reading and MNREAD methods were significantly different and were not correlated among tasks. These results suggest that these different reading tasks measure different aspects of reading behavior. Evaluating reading performance is an important clinical endpoint and a key quality of life indicator. However, the most effective test that is clinically meaningful is not clear.

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53.4051 Functional connectivity dynamics of the left midfusiform gyrus during single, printed word presentation

Matthew Boring[1,2,3](mjb200@pitt.edu), Rongye Shi[2,3,4], Michael Ward[3], Witold Lipski[3], Peter Elliot[5], Max G'Sell[5], Mark Richardson[2,3], Julie Fiez[6,7], Avniel Ghuman[2,3,4]; [1]Center for Neuroscience, University of Pittsburgh, [2]Center for the Neural Basis of Cognition, Carnegie Mellon University and University of Pittsburgh, [3]Department of Neurological Surgery, University of Pittsburgh, [4]Program in Neural Computation, Center for the Neural Basis of Cognition, Carnegie Mellon University and University of Pittsburgh, [5]Department of Statistics, Carnegie Mellon University, [6]Learning Research and Development Center, University of Pittsburgh, [7]Department of Psychology, University of Pittsburgh

The left temporal language network is largely understood in terms of various distinct brain regions with functions related to language processing, including those thought to support the process of transforming printed words into their phonological form and meaning. However, little is understood about how these regions communicate to accomplish these tasks. The aim of this study was to spatiotemporally characterize the functional connectivity between a core part of the network, the left midfusiform gyrus [lmFG] also known as the "visual word form area," and other regions of the brain during individual printed word presentation. By calculating phase locking values between intracranial electrodes and posterior probabilities derived from a 6-way Bayesian classifier, functional connectivity between electrodes and information content within electrodes could be visualized over time and space. The results of these analyses support the notion that two distinct stages exist in visual word form processing: an

early stage (150-200 ms), characterized by long range connectivity from the lmFG to more anterior and superior regions of the left temporal lobe, and a later stage (250-400 ms) where word form information tends to be more distributed throughout the left midfusiform and neighboring gyri. Taken together, these results support recent findings of multi-stage orthographic processing in the lmFG and that the dynamic shift from gist-level to individual-level word representation occurs through network-level interactions among regions of the language network. More focused experimental paradigms and network-based statistics are necessary to determine how information flows among these regions to support these multiple stages of orthographic processing, and how this sub-network fits into the larger language network.

53.4052 Temporal modulation of signal/noise reveals processing units of a scale greater than letters in visual word recognition. Simon Fortier-St-Pierre[1](simon.fortier-st-pierre@umontreal.ca), Martin Arguin[1]; [1]CERNEC, Département de psychologie, Université de Montréal

Visual word recognition is largely based on the identification of the letters making up the stimulus (e.g. Pelli et al., 2003). Some studies, however, suggest that units of a greater scale than letters (ranging from transletter features to whole words) also contribute to performance. This claim rests on the negative impact of aLtErNaTiNg CaSe across consecutive letters on reading performance (e.g. Mayall et al., 1997; Pelli & Tillman, 2007). One drawback of case alternation is that it may require observers to switch perceptual tuning between the recognition of uppercase and lowercase letters for every consecutive letter. This means that the cost of case alternation may lie in the letter identification process itself, thus making the result inconclusive with respect to the size of the processing units involved in word recognition. Here, we assess whether units of a scale greater than the letter effectively contribute to visual word recognition. We used a random temporal modulation of the signal-to-noise ratio of the stimulus that was either applied simultaneously throughout all the letters in the word (homogeneous condition) or separately and independently for each letter (heterogeneous condition). Temporal sampling functions were made from the integration of sine waves of 5, 10, 15, and 20 Hz, each with a random amplitude and phase. Stimuli were displayed on a 120 Hz monitor, their exposure (i.e. target + noise) lasted 200 ms and the duration of visibility of each letter was equated across conditions. Our results show significantly better word recognition performance in the homogeneous condition (72.5 %) in comparison to the heterogeneous one (59.3 %), a finding that is verified in each individual participant. The advantage for a temporal modulation of signal/noise that applies simultaneously across all the letters in a word demonstrates a significant contribution of processing units of a scale larger than the single letter.

53.4053 Representations of individual number and letter symbols in ventral visual cortex Daniel Janini[1](daniel.janini@nih.gov), Chris Baker[1]; [1]National Institute of Mental Health, Laboratory of Brain and Cognition

Identification of visually presented numbers and letters is an essential task in literate societies, yet the neural mechanisms of this behavior are still unclear. Recent studies have argued that specific regions of ventral visual cortex are selective for numbers (Grotheer et al., 2016) and letters (Thesen et al., 2012). Here, we completed an ultra-high resolution (7T) fMRI study to investigate whether these regions encode information about individual symbols. First, we determined whether separate number and letter selective regions could be found in ventral visual cortex. Next, we used multivariate pattern analyses (MVPA) to explore which regions of ventral visual cortex encode numbers and letters through different patterns of response to individual symbols. Two experiments were interleaved during a single scanning session: 1) a block design localizer using a one-back task, 2) an event-related experiment with presentations of individual letters and numbers. The localizer included blocks of numbers, letters, false numbers, and false letters. The event-related runs included five letters (c, d, e, f, g) and five numbers (3, 4, 5, 6 ,7) presented in four fonts. Candidate number and letter selective regions were defined as in previous research by contrasting numbers against false numbers and letters against false letters. These regions showed high overlap. Moreover, direct contrasts of numbers vs letters failed to reveal regions of interest. However, the localizer revealed bilateral regions responsive to both numbers and letters, and MVPA was completed within these regions using data from the event-related runs. These symbol-responsive regions showed different patterns of response for individual numbers and for individual letters. Thus, our results argue against separate regions of visual cortex showing univariate differences in response to numbers and letters. However, bilateral regions of ventral visual cortex responsive to both letters and numbers contain information about individual symbols in multivariate differences in neural response.

53.4054 Is word recognition crowded in pure alexia? Katrine Sand[1], Thomas Habekost[1], Anders Petersen[1], Randi Starrfelt[1]; [1]Department of Psychology, University of Copenhagen

Pure alexia is a selective deficit in reading, which arises following damage to the left ventral occipito-temporal cortex. Crowding, the inability to recognise objects in a clutter, has recently been hypothesised to be the underlying deficit of apperceptive visual agnosia1. Crowding normally occurs in peripheral vision, and we therefore tested whether the performance with words at the centre of fixation in a pure alexic patient (LK) is indeed similar to the performance of matched controls in the peripheral visual field. Using an accuracy-based word recognition task with brief, masked exposures, we tested word processing in LK and 24 matched controls. LK was tested in central vision, while the controls were tested in central vision and 4.6 degrees to the right of fixation. LK was significantly impaired on visual word recognition in the central visual field but there was no significant difference when comparing LK's performance in central vision and the performance of the controls at 4.6 degrees. The equivalent eccentricity1 was calculated by estimating the linear relationship between the mean performance across the exposure durations in the central and peripheral condition in the control group. Based on this, we found that the equivalent eccentricity of LK corresponds to 7.4 visual degrees, indicating that her visual word recognition is as bad as normal word recognition would be with stimuli presented 7-8 degrees from fixation. Our findings indicate that word recognition in pure alexia may be impaired by the same processing limitations that makes normal vision less efficient in the periphery than at fixation. Leaning on a recent proposal from Martelli et al.1, we suggest that central vision is crowded in pure alexia, and that this may at least partly explain the reading deficit. 1) Martelli et al. (2015). Journal of vision. 15(12): 921

53.4055 Musical notation reading in pure alexia Randi Starrfelt[1](randi.starrfelt@psy.ku.dk), Yetta Wong[2]; [1]Department of Psychology, University of Copenhagen, [2]Faculty of Education, the University of Hong Kong

Pure alexia (PA) is an acquired reading disorder following lesions to left ventral temporo-occipital cortex. Patients with PA read slowly but correctly, and show an abnormal effect of word length on RTs. However, it is unclear how pure alexia may affect musical notation reading. We report a pure alexic patient, KH, who was a highly skilled amateur musician before a stroke that resulted in PA (elevated reading RTs; word length effect; intact writing and language) and right hemianopia. KH experienced difficulties in note reading and playing by notes post-stroke. KH's visual short-term memory capacity was intact in the left visual field.1 We investigated KH's letter and note reading using simultaneous matching tasks with stimuli presented slightly to the left of fixation. KH was compared to 9 controls matched for age, education, and music reading experience, using single case statistics2. Accuracy was high in all experiments for KH and controls, but KHs RTs were elevated in some conditions: He showed significant deficits in matching words and pseudowords, but not unrelated letters. For musical notes, KH performed worse than controls when matching the pitch of four-note sequences. In a task where both pitch and duration information was present, KH was disproportionately slower in selectively attending to the pitch of single notes, particularly on match trials, while he performed normally when selectively attending to duration information. The exact same stimuli were used in both conditions, suggesting that KHs performance cannot be explained by a deficit in basic processing of visual features of musical notes or preferences in processing strategies. In sum, pure alexia may affect music reading selectively on pitch processing, in particular with longer music sequences, suggesting an impairment in judging relative position of the notes. 1 Petersen et al. (2016). Neuropsychologia, 92;79-89. 2 Crawford & Garthwaite (2002) Neuropsychologia, 40;1196-1208.

Acknowledgement: Danish Council for Indenpendent Research - Humanities

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 SEE PAGE 3 FOR ABSTRACT NUMBERING SYSTEM

53.4056 What enhances/reduces holistic processing in perceptual expertise: experience in writing/drawing versus component composition
Ricky Van-yip Tso[1,2](rvytso@eduhk.hk), Wai-ming Cheung[2], Terry Kit-fong Au[2], Janet Hui-wen Hsiao[2]; [1]The Education University of Hong Kong, [2]The University of Hong Kong

Holistic processing (HP) can serve as a behavioral marker of expertise in face and visual object processing, though this effect can be modulated by sensorimotor experiences. For example, people with face-drawing experiences viewed faced less holistically than ordinary observers. Similarly, while beginning readers of Chinese show an increase in HP of Chinese characters, expert Chinese readers with extensive experience writing Chinese characters show reduced HP. It is suggested that writing/drawing reduced HP by allowing observers to attend to the local components of visual stimuli (i.e., facial features and Chinese character components). The present study hence examined whether experience in attending to local components through component composition training leads to a similar reduce HP effect to writing/drawing experience in object recognition by training semi-novices to recognize Chinese characters. Second-language Chinese learners with limited experience writing Chinese characters were trained to recognize new Chinese characters via reproducing them using character component stickers (similar to doing jigsaw puzzles). Other participants were randomly assigned to two control conditions in which they were taught to recognize characters through a whole-word approach or copying. We found that training through component composition enhanced both holistic processing and orthographic awareness more strongly than training approaches through whole-character recognition and character copying. In contrast, character copying reduced HP marginally. It seems, then, attending to local component structure required by this novel character reconstruction method does not suffice to reduce HP of Chinese characters—perhaps sensorimotor experience or selective attention at the stroke level is crucial in modulating HP in Chinese character recognition. Nevertheless, this component composition training method is able to facilitate developing holistic mental representations of Chinese characters among beginner learners, which seem to mark the initial stage of acquiring expertise in Chinese character recognition.

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53.4057 Developing a logarithmic Chinese reading acuity chart
Cong Yu[1](yucong@pku.edu.cn), Qi-Ming Han[1], Ling-Juan Cong[1], Lei Liu[2]; [1]Department of Psychology, Peking University, [2]School of Optometry, University of Alabama at Birmingham

An individual's reading ability cannot be reliably predicted from his/her letter acuity, contrast sensitivity, and visual field extent. We developed a set of Chinese Reading Acuity Chart (C-READ for short) to assess the reading ability of Chinese readers, based on the collective wisdom of previously published reading acuity charts, especially the Minnesota Low-Vision Reading Test and the Radner Reading Charts. The C-READ consists of three charts. Each is made of sixteen 12-character Simplified Chinese sentences crafted from 1st-3rd grade textbook materials. Thirty Chinese college students tested the reliability of C-READ with corrected vision. Another thirty-two students validated the C-READ with the International Reading Speed Test (IReST) with corrected- and uncorrected-near vision. The reading acuity, critical print size, and maximum reading speed for young normal native Chinese-speaking readers were 0.16 ± 0.05 logMAR, 0.24 ± 0.06 logMAR and 273.44 ± 34.37 characters/minute (mean ± SD), respectively. The reliability test revealed no significant differences of reading acuity, critical print size, and maximum reading speed among three C-READ charts and no significant test order effect. Regression analyses showed that the maximum reading speed of C-READ could reliably predict the IReST reading speed with corrected near vision (adjusted $R2 = 0.72$). Moreover, the maximum reading speed and the critical print size could together reliably predict IReST reading speed with uncorrected near vision (adjusted $R2 = 0.69$). The C-READ is a reliable and valid clinical instrument for quantifying reading performance in simplified Chinese readers.

Acknowledgement: Supported by a Natural Science Foundation of China grant

53.4058 Defining letter similarity
Deyue Yu[1](yu.858@osu.edu), Tae Kyu Kwon[1]; [1]College of Optometry, Ohio State University

In letter identification, confusion probabilities are often used to define letter similarity. The goal of this study is to develop a universal, objective method to quantify letter similarity. Since letter similarity may be associated with the number of similar features shared by the letter pair, we started with identifying 22 potential letter features that appear universally across everyday fonts. A san-serif font, Century Gothic, was used for letter feature analysis. Only lowercase letters were considered. Customized Matlab scripts were used to process letter images and to detect and quantify letter features for each letter, following which similarity score between each pair of letters was calculated. There were 22 sets of similarity scores, one for each feature. To assess the amount of variation in letter confusion probability accounted for by the similarity scores, we performed linear regression analyses (considering only the linear terms). Four confusion matrices measured with different fonts under different testing conditions (Bouma, 1971; Geyer, 1977; McGraw et al., 1994) were examined. Despite the usage of different fonts in calculating similarity scores and obtaining confusion matrices, the best fitting models explained about 30% of the variability of letter confusion across the four confusion matrices. Ten letter features (e.g., number of separated parts, parallelism, and closed area) consistently showed significant contributions to the errors in letter identification. These findings suggested that defining letter similarity in a universal, objective way is feasible.

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53.4059 Hemifield-dependent fMRI repetition enhancement for word pairs with concomitantly repeated and added letters
Zhiheng Zhou[1](zhzhou44@gmail.com), Carol Whitney[2], Lars Strother[1]; [1]Department of Psychology, University of Nevada, Reno, [2]Independent Researcher

Results from fMRI repetition studies of whole-word representation implicate a visual word form area (VWFA) in left occipitotemporal cortex. We used a rapid event-related fMRI partial word repetition paradigm to study the effects of repeating all letters of a word and concomitantly adding a letter, either at the end of the word or at the beginning (e.g. CAR → CART or CAR → SCAR), as compared to words that changed in full (e.g. CAR → DESK); we also varied the hemifield location of words within a pair, which either matched or not. Our main goal was to identify voxels showing repetition suppression for repeated letters in the context of a change in the meaning of a word. Results of previous studies (Strother et al. 2016; Glezer et al. 2009) led us to expect repetition suppression in an occipital word form area (OWFA), and possibly portions of retinotopic visual cortex, but not in the VWFA. Surprisingly, we observed little if any evidence of repetition suppression in any of our targeted cortical regions. We instead observed a single consistent locus of "repetition enhancement"—the VWFA—for partially repeated word pairs relative to fully changing words, even when each word within an event pair was viewed in an opposite visual hemifield. The sole exception to this effect was observed for word pairs in which both words appeared in the left visual hemifield. Our results suggest reactivation of letters shared between two words when these letters represent a real word, but only when at least one of the words appears in the right visual field, contralateral to the VWFA. We interpret our results in relation to the interhemispheric transfer of visual word form information and whole-word representation in the VWFA.

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3D Perception: Space

Tuesday, May 23, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.4060 The contributions of monocular and binocular signals to the perception of 3D motion
Mohan Ji[1](mji24@wisc.edu), Lowell Thompson[2], Ari Rosenberg[2,3], Bas Rokers[1,3]; [1]Department of Psychology, College of Letters and Science, University of Wisconsin-Madison, [2]Department of Neuroscience, School of Medicine and Public Health, University of Wisconsin-Madison, [3]McPherson Eye Research Institute, University of Wisconsin-Madison

More than half of typically sighted observers have difficulty perceiving three-dimensional (3D) motion. Specifically, these individuals are unable to discriminate the direction of motion-in-depth (i.e., "towards" vs. "away") within spatially restricted regions of the visual field. This deficit appears

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to result from impairments in the integration of binocular motion signals. Even though the perceptual experience of 3D motion is absent, the sensory signals required for 3D motion perception are available, as evidenced by normal sensitivity to frontoparallel motion and static binocular disparity. As such, we previously characterized this deficit as an agnosia specific to 3D motion. Here we extend these findings by investigating the contribution of monocular cues to 3D motion perception in both affected and unaffected individuals. Participants sat 90 cm from a display containing dots moving either towards or away from them within a simulated cylindrical volume (1.5° diameter, 12 cm depth). On each trial, a 3D motion stimulus appeared in one of 40 locations arranged in a spoke-wheel pattern with eccentricity ranging from 1.5° to 7.5°. Stimuli contained monocular, binocular, or both cues to 3D motion. Sensitivity to each cue was assessed by varying dot motion coherence. Our results show considerable variability in the sensitivity to monocular and binocular cues across observers. However, all observers integrate the two cues near-optimally. Furthermore, the previously established deficit in perception of 3D motion appears to be specific to stimuli containing only binocular cues. Perception based on monocular cues seems to be unaffected. These results show that the deficit results from a spatially restricted impairment in the integration of binocular cues to motion-in-depth. In future studies, we aim to uncover the neural basis of this deficit in 3D visual motion perception using brain imaging (fMRI/DTI) in humans, and neural recordings in non-human primates

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53.4061 **The outdoor perception of distance ratios** J. Farley Norman[1](farley.norman@wku.edu), Olivia Adkins[2], Catherine Dowell[1], Lindsey Shain[1], Stevie Hoyng[1], Jonathan Kinnard[3]; [1]Department of Psychological Sciences, Ogden College of Science and Engineering, Western Kentucky University, [2]Department of Psychological and Brain Sciences, Indiana University, [3]Carol Martin Gatton Academy of Mathematics and Science, Bowling Green, Kentucky

Thirty-two participants judged distances in an outdoor setting. Half of the participants were younger than 30 years, while the remaining half were older than 60 years. The participants' task on each trial was to view two environmental exocentric distances and estimate the distance ratio (i.e., the magnitude of the longer extent relative to the shorter). The individual distance magnitudes ranged from 6.4m to 55.2m. The maximum stimulus distance ratio was 8.0. All of the participants could reliably judge the distance ratios: the mean correlation coefficient relating physical and judged distance ratios was 0.762. The majority of participants, however, underestimated the distance ratios and perceived them to be smaller than they actually were. There were effects of both age and sex. The male participants' estimated distance ratios were 19.1 percent more precise than those of the female participants, while the judgments of the older males were more accurate than those of the younger participants and older females (the slopes of the older males' functions relating judged and actual distance ratios were 55 percent higher, and much closer to 1.0, than those of the other participants).

Acknowledgement: This research was supported by Kentucky NSF EPSCoR (National Science Foundation award #1355438)

53.4062 **Manipulations of local, but not global, luminance gradients affect judgements of depth magnitude** Paul Hibbard[1](phibbard@essex.ac.uk), Ross Goutcher[2], Naveed Khan[1], Rebecca Hornsey[1]; [1]Department of Psychology, University of Essex, [2]Psychology, University of Stirling

In local image neighbourhoods, points in the scene that are closer to the observer tend to be brighter (Potetz and Lee, 2003). When images are manipulated to exaggerate or reduce this, the quality of the resulting 3D experience can be enhanced or diminished (Cooper and Norcia, 2014). We assessed whether this affected the magnitude of depth perceived and whether this was a local or a global effect. We created scenes using a collection of scanned 3D objects, rendered stereoscopically, and manipulated the luminance of individual pixels to enhance or reduce the relationship between distance and luminance, either globally or locally. In the global enhancement condition, the mean luminance of each object was increased or decreased depending on whether it was nearer or further away than the mean object distance, in proportion to its distance from the mean. In the global reduction condition, the luminance of nearer objects was reduced, and that of further objects increased. In the local conditions, similar manipulations were made to the luminance of individual pixels on each object, depending on their position in depth relative to other pixels belonging to that object. On each trial, two dots were overlaid on the scene, either on different objects (global condition) or on the same object (local condition). The observer's task was to set the length of an onscreen ruler to match the 3D distance between the two points. The luminance manipulation had no effect in the global condition. In the local condition, greater depth was perceived in the enhanced condition, for both stereoscopic and non-stereoscopic viewing. These results show that the manipulation of the statistical relationship between distance and luminance influences perceived depth. Consistent with the statistics of natural scenes, this effect is local, and did not affect perceived depth in the global condition.

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53.4063 **Contextual influences of room width and depth on egocentric distance judgments in natural scenes** John Philbeck[1](philbeck@gwu.edu), Dwight Kravitz[1], Stephen Mitroff[1], Lindsay Houck[1]; [1]Department of Psychology, The George Washington University

Environmental context is known to influence visual space perception, but characterizing the underlying mechanisms poses many challenges. Natural environments are heterogeneous and complex. Thus, it is difficult not only to match environments across experiments and labs, but also to identify relevant scene features out of the great multiplicity of possibilities. These constraints motivate a need for extensive data collection to evaluate candidate hypotheses. Using rendered scenes and Amazon's Mechanical Turk, the current study provides a means of meeting these challenges, and focuses specifically on the possible role of room size on distance judgments. Stimuli were empty rooms lined with irregularly-placed doors; rooms varied in depth (6-40m) and width (1.5-40m), with an orange cone placed 2–37 m from the observer's viewpoint. 100 MTurk workers numerically judged the cone distance, with 11,484 collective judgments being completed in 3.5 hours. Analysis of 4 widths x 3 depths x 6 distances (2–4.8m) showed a main effect of room depth (p=0.012); deeper rooms were associated with shorter distance judgments, averaging 2.09 vs. 2.18m for 40m vs. 6m room depths, respectively. There was no effect of room width (p=0.159). Analysis of 4 widths x 14 distances (2 – 37m; 40m room depth only) showed a main effect of width (p< 0.001); wider rooms were associated with larger distance judgments (averaging 8.12 vs. 10.28m for 1.5m vs. 40m room widths, respectively). For targets at 37m, mean judged distances differed by over 8m between 1.5 vs. 40m width rooms. This indicates that visual features well outside the nearby ground plane can play a role in environmental context effects. Given past evidence of rapid extraction of mean depth based on global image features, we propose that similar global processes participate in scaling the perceived egocentric distance of objects in the environment.

53.4064 **Distance Perception in Consumer Virtual Reality** Rebecca Hornsey[1](rlhornsey@outlook.com), Paul Hibbard[1], David Hunter[2]; [1]Department of Psychology, University of Essex, [2]Department of Computer Science, University of Aberystwyth

The perception of distance is known to be compressed in virtual reality in comparison with the real world (Creem-Regehr, Stefanucci and Thompson, 2015). This compression has been attributed to errors in the calibration of the view frustrum and it has been shown that distance perception is more accurate when these errors are removed (Ponto, Gleicher, Radwin and Shin, 2013). We investigated the accuracy of distance perception in consumer virtual reality using a distance bisection task. Stimuli were created using Unreal Engine and presented using an HTC Vive, following a standard room scale calibration. Participants were presented with two spheres at eye height. On each trial a reference sphere was presented at a distance of between 1 and 10m, at intervals of 1m. The participants adjusted the dis-

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tance of a target sphere so that it appeared to be at half the distance as the reference. Across this range distance bisection settings were accurate and there was no evidence of distance compression for distances of between 1 and 10m. This demonstrates that consumer virtual reality can be used in applications for which accurate distance perception is important.

Acknowledgement: BBSRC grant BB/K018973/1 grant to PBH and DWH

53.4065 Observer vantage point and layout of virtual pictorial space Dejan Todorović[1](dtodorov@f.bg.ac.rs); [1]Laboratory of Experimental Psychology, Department of Psychology, University of Belgrade, Serbia

Every image executed according to the rules of linear perspective, such as a photograph, has a center of the perspective construction. Only when viewed from this location does the imaged scene exactly project into its picture. However, in everyday viewing of images the choice of an appropriate vantage point is not recognized as a problem, and very few observers even know of the existence of such geometrically privileged observation locations. It has been suggested that the visual system tolerates large deviations from the projectively correct vantage point, or that mechanisms exist that actively compensate for incorrect vantage points. However, there are studies that indicate that different choices of vantage points do induce different impressions of geometrical layouts of virtual 3D spaces conveyed by the same image. Here I present a series of experiments that demonstrate such effects. The image used as the stimulus was a photograph of a street receding obliquely into distance, and the task of the subjects was to judge its orientation with respect to the environment. In the first experiment the image was presented as a large billboard at a city intersection, and the subjects were located at various directions and distances around it. In the second experiment it was presented as a poster hanged in a hall, and the subjects were located at two distances and four directions from it. In the third experiment the same image was embedded in a computer-generated virtual scene and depicted from several vantage points. The results have indicated strong and systematic effects of vantage point positions on the perceived orientation of the street. They can be generally accounted for by the assumption that the visual system treats the image as the projection of a scene from the perspective center located at the current vantage point of the observer.

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53.4066 Comparison of the visual and haptic horizontal-vertical illusion Tyler Surber[1](tyler.surber@usm.edu), Joseph Clark[1], Jonathan Doyon[1], Catalina Olavarria[1], Alen Hajnal[1]; [1]University of Southern Mississippi

The Horizontal-Vertical illusion is a phenomenon in which participants underestimate the length of horizontal lines when compared to vertical lines of the same length (Yang, Dixon, & Proffitt, 1999). The illusion is traditionally thought of as only a visual phenomenon in geometric tasks. The present project sought to demonstrate that the illusion occurs in haptic perception as well. Three groups of participants provided matching judgments in three conditions: (1) haptic perception with visual matching, (2) visual perception with visual matching, and (3) combined visual and haptic perception with visual matching. In condition (1), participants haptically manipulated vertically positioned wooden dowels of various lengths, then attempted to match the length of the dowel with a horizontal pulley system positioned frontally with respect to the participant. In condition (2), participants viewed vertically positioned wooden dowels of various lengths, then attempted to match the length of the dowel with a horizontal pulley system positioned frontally with respect to the participant. In condition (3), participants both viewed and were permitted to manipulate through wielding vertically positioned wooden dowels of various lengths and then attempted to match the length of the dowel with the same pulley system used in conditions 1 and 2. Results indicated no differences between the three experimental conditions: haptic, vision, and combined (haptics and vision). Regardless of condition, participants underestimated the dowel length in the horizontal orientation. The current experiment offers support for the Horizontal-Vertical Illusion affecting the haptic system. Additionally, the lack of differences between experimental conditions offers support for Gibson's (1979) theory of equivalence in perceptual systems.

53.4067 Role of senses in representing portions of spaces around our body. Elena Aggius-Vella[1](elena.aggius-vella@iit.it), Claudio Campus[1], Monica Gori[1]; [1]U-VIP, Istituto Italiano dI Tecnologia

Vision has a central role in the development of spatial skills of other senses. Most of the studies on auditory spatial representation have focused on the frontal space, especially at head level. Few is known about the role of senses in representing spaces where vision is not available (i.e. in the back space) and around other body spaces (i.e. around the foot, where walking produces audio feedback of movement). To clarify these points, we performed a sound localization task by manipulating the sound's source (front vs. back and at thigh vs. at foot level) and sensory experiences (by testing sighted and blind people). We hypothesized that visual calibration on hearing could spread over all spaces around the body, but hearing may have a special role in representing the rear space and the space around foot. We adopted a generalized linear mixed model where the answers of each subject were regressed as a function of sound level (thigh vs foot level) and longitudinal position (front vs rear space) as factors within subjects, while group (blind vs sighted) as factor between subjects. Results supported our hypotheses by showing that sighted people were similarly accurate in localizing frontal and rear sounds, while blind people were more accurate in localizing rear sounds. Furthermore, by comparing the two groups, we found that sighted people were more accurate on the frontal zone than blind, while blind performed better than sighted in the rear space. Summarizing, our study showed that space around us could be split in different portions where senses and visual experience have a different weight.

53.4068 Visual and haptic perception of the affordance of upright stance. Catalina Olavarria[1](Catalina.Olavarria@usm.edu), Tyler Surber[1], Joseph Clark[1], Jonathan Doyon[1], Alen Hajnal[1]; [1]Department of Psychology, University of Southern Mississippi

Past research by Hajnal, Wagman, Doyon, and Clark (2016) found apparent differences among haptic and visual perception of the affordance of stand-on-ability. One reason for this discrepancy might be due to the imprecision and method of measurement. Instead of using the classic psychophysical method of constant stimuli, we employed a dynamic converging staircase method of stimulus presentation. Our goal was to obtain a reliable estimate of perceptual and action boundaries within a behaviorally relevant precision level of 1.5 degrees of geographical slant. We used an adjustable sturdy ramp apparatus as the stimulus, and had three groups of participants either visually inspect the surface, place their right foot occluded from view unto the ramp surface, or place their foot on the ramp while allowed to look at it, in the visual, haptic, or full cue condition, respectively. Each trial was presented in an ascending or descending fashion by slowly moving the ramp up or down, respectively, until the participant perceived the action boundary, i.e. the steepest slope that still afforded upright stance. After the perceptual trials we measured the actual action boundary using the same procedure, by allowing participants to attempt to stand on the ramp. The action boundary was the average between the lowest false alarm trial and steepest hit trial within a 1.5 degree margin of difference based on several ascending and descending stimulus presentation sequences. The results revealed that visual and haptic perception were equivalent with the combined condition, and that all corresponded to the action boundary. Curiously, it took more attempts to detect the action boundaries than perceptual ones. The results support the postulate of equivalence among perceptual systems proposed by Gibson (1966), and the idea of correspondence between perception and action which is the cornerstone of affordance theory.

53.4069 Illusory Motion and Kinetic Poggendorff Illusions in Baseball: Baserunners and Vantage Can Bias Perception of Ground Ball Trajectories Michael McBeath[1](m.m@asu.edu), Crystal Oberle[2]; [1]Department of Psychology, Arizona State University, [2]Department of Psychology, Texas State University

Introduction: This study tests conditions conducive for spatial illusions in a naturalistic, 3-D, real-world, baseball setting. We examined perceptual judgments of ground ball destinations by peripheral stationary observers compared to nearby active fielders. Methods: A 3m by 21m tarp covered a barricade between 1st and 2nd base, 0.5m off the ground. Participants estimated where ground balls from home plate would emerge if not for the barricade. 0, 1, 2, or 4 simultaneous baserunners ran perpendicular to the ground balls to test for induced motion effects under real-world sporting conditions. 112 participants over three experiments observed and estimated where the ball would exit from under the tarp if there were no barrier. Active participants ran along the back edge of the tarp touching it above where they believed the ball would have exited. Results: Our findings revealed a robust kinetic Poggendorff illusion (offset mean=74cm) for stationary observers that only minimally diminished when they were near the ball destination location, but no significant distortion occurred for active fielders (offset mean=5cm). In addition, though there were no significant differences between the 1, 2, or 4 baserunner conditions, their average produced robust illusory motion opposite the direction of the baserunners (offset mean=35cm), but that once again produced no significant distortion for the active fielders (offset mean=8cm). Discussion: The findings confirm robust spatial illusions occur in naturalistic, real-world environments like a baseball setting, but only for stationary observers and not active moving fielders. The findings are consistent with other research that supports two independent perceptual systems, an illusion-prone ventral or "what" system used for constructive stationary predictions of space, and an illusion-resistant dorsal or "how" system used to control ongoing, interactive perception-action movements. The findings support that robust spatial illusions occur in real-world sport settings, but generally not with sporting actions.

Acknowledgement: NSF Grants BCS-0318313 and 0403428

53.4070 Matching corresponding visual areas with fMRI and MEG

Phoebe Asquith[1](asquithpm@cardiff.ac.uk), Simon Rushton[1], Beth Routley[1], Krish Singh[1]; [1]School of Psychology, Cardiff University

fMRI and MEG have complementary strengths. fMRI offers high spatial resolution, MEG offers high temporal resolution. The challenge is combining information from the two technologies. We recorded BOLD while observers watched a 25min clip of the Skyfall film in a 3T MRI scanner. We used ICA to segment the visually responsive areas of the cortex into clusters of voxels with similar timecourses (and hence tuning for visual features). The timecourse of each cluster (ICA component) was extracted. Observers watched the same film clip in a MEG scanner. Using SAM, we projected the sensor data into synthetic voxels in an anatomical coordinate frame to match the fMRI data. For each voxel, for each frequency band, from delta to ultra gamma, at a temporal resolution of 2 seconds (to match the fMRI data acquisition), we calculated the power (magnitude of the Hilbert envelope). We then cleaned the MEG data and convolved it with a BOLD haemodynamic response function. Using a standard GLM analysis we searched for MEG voxels with timecourses that correlated with the timecourses of a selection of the fMRI-ICA components. From the fMRI data we chose candidate components on the lateral and medial surface of occipital lobe. We found activation in comparable anatomical locations in the MEG data. The use of extended (~20min) broadband visual stimuli (film clips) that impose a temporal structure, coupled with ICA, is a promising way to segment the visually responsive cortex and match across imaging modalities.

Acknowledgement: EPSRC

Binocular Vision: Stereopsis

Tuesday, May 23, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.4071 On the combination of illusory and luminance-defined stereoscopic surfaces

Brittney Hartle[1](brit1317@yorku.ca), Richard Murray[1], Laurie Wilcox[1]; [1]Department of Psychology, and Centre for Vision Research, York University

In stereoscopic Kanizsa figures the shape of the interpolated illusory surface is determined by luminance-defined disparity signals that exist only along edges of inducing elements. Despite ambiguity in the position of illusory boundaries, observers reliably perceive a coherent surface in depth between the inducers. However, the ambiguity of illusory boundaries may contribute additional uncertainty in the depth percept beyond what is expected from measurement noise alone. We evaluated the intrinsic uncertainty of illusory boundaries by measuring the reliability of depth percepts elicited by stereoscopic illusory surfaces using a cue combination paradigm. We systematically assessed the accuracy and precision of suprathreshold depth percepts using Kanizsa figures with a range of inducer disparities. For comparison, we assessed perceptually equated luminance-defined surfaces, with and without inducing elements. The location of the surface peak in these configurations was defined by illusory boundaries, low contrast luminance-defined edges, or a combination of both. Accuracy was evaluated using a disparity-matching procedure and precision was assessed using a 2IFC depth discrimination paradigm. A maximum likelihood, linear cue combination model was used to evaluate the relative contribution of illusory and luminance-defined signals to the perceived depth of the combined surface. Our analysis showed that the variance in estimated depth was consistent with optimal combination, but the points of subjective equality (PSE) showed that observers consistently underweighted the contribution of illusory boundaries. This systematic underweighting is consistent with a combination rule that attributes additional intrinsic uncertainty to the location of the illusory boundary due to the lack of luminance-defined features that define its location in 3D space. While previous studies have shown that illusory and luminance-defined contours are processed similarly in some ways, our results demonstrate that illusory contours have additional intrinsic uncertainty beyond what we would expect from perceptually matched luminance-defined contours.

Acknowledgement: NSERC Discovery

53.4072 Effects of temporal frequency on binocularity and contrast sensitivity in amblyopia

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Amblyopia is associated with a range of visual deficits, including reduced contrast sensitivity, interocular suppression, and impaired stereopsis. Binocular interactions are modulated by temporal frequency in normally-sighted observers; for example continuous flash suppression can be induced by monocular flicker. We examined the effects of temporal frequency on contrast sensitivity and binocular interactions in adults with amblyopia (n = 5) and normally-sighted control subjects (n = 16). For each observer, we estimated the temporal contrast sensitivity function (tCSF) monocularly in each eye using a modified quick CSF procedure (Lesmes et al., 2010) with bandpass-filtered letters at four spatial frequencies (1, 2, 4, and 8 cpd). Results showed greater interocular differences in the area under the tCSF in amblyopes compared to controls, but only at high (4 and 8cpd) spatial frequencies ($F = 2.82$, $p = .047$), indicating that amblyopes have a preserved ability to process temporal information at low spatial frequencies. We also evaluated binocularity by measuring interocular suppression and stereoacuity thresholds across four temporal (0, 4, 7.5, and 12 Hz) and spatial (1, 2, 4, and 8 cpd) frequencies. Interocular suppression was estimated by varying the contrast ratio of two dichoptic letters to produce perceptual reports of each letter with equal frequency (Kwon et al., 2014). Stereoacuity thresholds were measured by determining the minimum disparity at which subjects identified a front-depth target with 75% accuracy in a 3AFC task. Across both groups, interocular suppression was lower at higher temporal frequencies ($F = 3.50$, $p = .02$), whereas stereoacuity thresholds were unaffected by temporal frequency ($F = 0.43$, $p = .73$). Our results point to a temporal dependence of amblyopic deficits, a dissociation between the effects of flicker on interocular suppression and stereopsis, and suggest that temporal modulation may be used to attenuate interocular suppression.

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53.4073 Interactions between horizontal and orientation disparities in stereopsis

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Stereoscopic vision is based on binocular disparities that correspond not only to spatial displacements between the images projected to the two retinas, but also other differences such as orientation disparities (Kato et al., 2016, Phil. Trans. R. Soc. B). We present here behavioral experiments to test this recent model. Observers viewed stereoscopically two types of stimuli presented in fovea: two parallel thin lines or the same lines connected with horizontal segments. The lines could be either oriented vertically or tilted by an angle up to 60 degrees. After a short (200 ms) presentation, observers reported which line appeared closer in depth. In a first experiment, the lines were presented only with horizontal disparities between the two eyes. In a second experiment, the lines were still parallel in each monocular image, but small orientation disparities were introduced between the two eyes. The difference between the two experiments created different percepts of parallelograms that were more or less slanted about the horizontal axis. In the

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first experiment, we found large shifts of the points of subjective equality in opposite directions for clockwise and counterclockwise tilts and worse sensitivity as tilt increased. The biases were even larger for closed contours. In the second experiment, we found that sensitivity was quite stable across different tilts. Our results suggest that observers have a preferred representation of a slanted plane that is closer to the one displayed in experiment 2. This preferred object appears to correspond to an object mostly slanted about a vertical axis, with little additional slant about the horizontal axis. The closed contour condition is presumably providing stronger evidence for a single plane in the visual scene. Our results are another example of interactions between orientation and horizontal disparities in the visual system (Farell, 2006, J. Neurosci.) that awaits to be tested physiologically.

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53.4074 **Rapid adaptation in stereopsis** Cherlyn Ng[1](cherlyn.j.ng@gmail.com), Bart Farell[1]; [1]Institute for Sensory Research, Syracuse University, Syracuse, NY 13244

Adaptation is a canonical computation that compares stimuli in the context of the temporal history and spatial surround. Adaptation maximizes neurons' dynamic range, stabilizes activity despite large environmental variations, is energetically efficient, improves discrimination thresholds and enables perceptual constancy. However, the consequences are aftereffects that shift percepts away from the adaptor and reduce sensitivity to the adapting stimulus. Classical experiments use these aftereffects to quantify adaptation with the adapting stimulus typically presented for tens of seconds. However, since saccadic latency can be in the order of milliseconds, humans should be able to adapt at much shorter timescales as well. There is physiological evidence for such rapid adaptation, and a report that it is perceptually apparent in auditory encoding. We ask here if stereopsis, which is thought to have sluggish dynamics, is susceptible to rapid adaptation. To that end, the adapting stimulus was presented for 500ms prior to a test stimulus that also lasted the same duration. Both adaptor and test stimuli were full-field dynamic random dot stereograms that could either be nearer or farther than the fixation cross. We investigated the effect of depth polarity and magnitude of the adaptors on stereo-thresholds and biases. 3/3 subjects demonstrated higher thresholds when the adaptors were of the same depth polarity as the test. Adaptors with large disparities were more effective in reducing performance than small-disparity adaptors. Consistent with the presence of aftereffects, adaptors that were nearer than the fixation biased responses towards positive disparities and vice versa. Accommodation and vergence movements during adaptation cannot explain these results because performance would be reversed if that were the case. Hence, we conclude that stereopsis can adapt to brief stimuli presentations and is well poised for rapid changes to local visual stimulation.

Acknowledgement: NSF Grant BCS-1257096

53.4075 **The fusional range of the periphery** Saeideh Ghahghaei[1](saeideh@ski.org), Suzanne McKee[1], Preeti Verghese[1]; [1]The Smith-Kettlewell Eye Research Institute

We investigated how the fusional range scales with eccentricity. Specifically, we measured the fusional range in the fovea and at 10 degrees below fixation. The limits of Panum's area are usually measured by increasing the disparity until the target appears "fuzzy". This is a poor method for the periphery as targets often appear fuzzy, even when presented with zero disparity. Here, we used a more rigorous method to determine the uppermost limit of fusion. At long durations, the two half-images that define a large disparity appear as two isolated targets in the same flat plane; small incremental changes in disparity produce changes in the separation between the half-images and disparity magnitude can be judged on the basis of separation, just like a monocular width judgment. The fusion limit is the point at which the threshold for judging dichoptic separation between the half-images is equal to the width threshold for monocular targets with the same separation. The targets were two patches of dynamic random dots. For dichoptic viewing, the reference target was presented in the fixation plane while the test target had a standing pedestal disparity. Participants made incremental judgments of disparity around this pedestal. For monocular presentation, two patches were shown to one eye and participants judged the width between the targets. Thresholds for incremental disparity and width discrimination were plotted as a function of the pedestal disparity or width. For both fovea and periphery, dichoptic thresholds initially increased with pedestal and then decreased until they matched the monocular thresholds. The fusional range at 10 degrees was a factor of 2-4 times larger than the fovea - smaller than eccentricity scaling for cortical magnification (5-6) or for hyperacuity (10 – 15). Our estimate is consistent with Ogle's (1954)'s estimate of fusion at 10 deg along the horizontal meridian.

Acknowledgement: The Smith-Kettlewell grant

53.4076 **Depth adaptation of disparity corrugated surface involves phase- and orientation-independent processing** Shufang He[1](heshufang001@126.com), Hiroaki Shigemasu[2]; [1]Graduate school of Engineering, Kochi University of Technology, [2]School of Information, Kochi University of Technology

Although depth adaptation has been widely studied by using disparity-defined surfaces, the level of adaptation still need to be clarified, especially for the disparity corrugated surface. To investigate whether multi-level processing is involved, we examined the phase- and orientation-independency of depth adaptation. Using dynamic random-dot stereograms, we tested the depth aftereffects of sinusoidal corrugations that were defined by horizontal-, vertical-oriented and combinations of these two orientations (plaids) in phase static and randomly changing conditions. In each condition, two adaptors with 20.2 arcmin and 4.1 arcmin amplitudes were presented at the left and right sides of the CRT monitor simultaneously for 6 s. The sides for the large and small adaptors were randomly counterbalanced. The test (12.1 arcmin) and comparison stimuli (in the range of 9.1 - 15.2 arcmin, nine levels) were also presented in the same way but only 0.5 s time duration. Participants were asked to judge which side had the larger amplitude and PSE was calculated. Also, using the same stimuli in phase changing condition, we tested the aftereffects that were adapted to horizontal-oriented corrugations, but probed by vertical-oriented corrugations, and vice versa. Although the results showed a little larger aftereffects in phase static condition which might be due to the retinotopic level adaptation, there were still obvious aftereffects in phase changing condition. These suggest the higher level phase-independent adaptation. The similar degree of aftereffects in phase changing condition induced by plaids stimuli as those by horizontal- or vertical-oriented corrugations was found, suggesting no interference of the combination with different-oriented sinusoidal corrugations. Moreover, the different-oriented adaptors and test probes caused the similar degree of aftereffects as the same orientation pairs. These results suggest the depth adaptation is orientation-independent, and it has a significant relationship with the peak-trough disparities of the adaptors, while not related to the retinotopic position.

53.4077 **Classification images for the perception of binocular slant** David Hunter[1](rasterburns@gmail.com), Paul Hibbard[2], Rebecca Hornsey[2]; [1]Prifysgol Aberystwyth University, [2]University of Essex

Two possible mechanisms have been proposed for binocular slant detection in the visual cortex: (1) binocular differences in orientation (Sanada & Ohzawa 2006) and (2) variations in binocular position differences across the surface (Bridge & Cumming 2001). The possible contributions of these two forms of binocular disparity have proved difficult to disentangle since the two are confounded on slanted surfaces. We used reverse correlation to find binocular classification images for a task in which observers judged the slant of Gabor stimuli slanted around a horizontal axis. On each trial, the Gabor was slanted so that the top was either nearer or further away, and the observer's task was to judge the direction of slant. Oriented, bandpass noise, which was uncorrelated between the left and right eyes' views, was added to the stimuli. The cyclopean orientation of the stimuli was varied to prevent classification by monocular orientation. 4 observers completed a total of 15900 trials. The classification images show vertically oriented structures in both left and right views, rather than a difference in orientation between the eyes. We also found evidence of phase difference in the classification images between left and right views, consistent with the use of position or phase disparities. This provides psychophysical evidence against the use of orientation disparity in the perception of binocular slant.

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53.4078 **'What not' encoding facilitates stereoscopic depth judgments** Andrew Welchman[1](aew69@cam.ac.uk), Nuno Goncalves[1]; [1]Department of Psychology, University of Cambridge, UK

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Current understanding of stereopsis emphasises the detection of matching features between the eyes (i.e., 'solving the correspondence problem') so that the depth of objects in the world can be triangulated and 'false matches' discarded. While this seems intuitive, binocular images naturally give rise to multiple mismatched features, and many V1 neurons appear optimised for binocularly incongruent stimuli. Here we propose an alternative approach, based on optimal information encoding, that mixes disparity detection with proscription: actively ruling out alternative interpretations by exploiting dissimilar features. We develop a psychophysical demonstration involving discriminating a step edge depicted in random dot stereograms (RDS). We quantified the masking effect of adding anticorrelated dots (aRDS: e.g., bright dot in one eye paired with a dark dot in the other) to an edge depicted using correlated stimuli (cRDS: e.g., bright dots match bright dots). While V1 neurons encode disparities in aRDS (Cumming & Parker, 1997), these stimuli are traditionally understood to stimulate 'false matches' that are discarded by the brain. Participants judged which side of the step was closer to them. We measured thresholds by changing the relative proportion of correlated vs. anticorrelated dots in the display. Our critical manipulation changed the disparity configuration depicted by the anticorrelated dots: unbeknownst to the viewer, this was either the same vs. opposite that specified by the cRDS. Masking was much stronger when correlated and anticorrelated dots specified the 'same' disparity configuration. This is expected from proscription: anticorrelation drives suppression of the encoded disparity, thereby making the correlated depth harder to see. Control measurements ruled out explanations based on residual perceptual sensitivity to aRDS disparity per se. We capture these findings in a Binocular Likelihood Model that provides a principled means of translating between disparity detection vs. proscription when estimating the most likely depth structure of a viewed scene.

Acknowledgement: Wellcome Trust

53.4079 Customizing mirror-prism haploscopes for viewers' interpupillary distance using 3D-printed adjustments Attila Farkas[1](ajf215@ruccs.rutgers.edu), Thomas Papathomas[1,2], John Papayanopoulos[3]; [1]Laboratory of Vision Research/Center for Cognitive Science, Rutgers University , [2]Department of Biomedical Engineering, Rutgers University, [3]Mechanical Engineering, College of Engineering, Georgia Institute of Technology

Introduction: Recovering depth from stereo image pairs is known to have difficulties (Hoffman et al., 2008; Kim et al., 2012). The main issue: Poor matching of the distance between the two eyes' images and the placement of the eyes' prisms. We describe results with a hardware/software method enabling the precise adjustment of the horizontal position of images and the viewing prisms of the haploscope. Methods: A two-piece apparatus was added to prism-and-mirror haploscope that was initially designed with a fixed interpupillary distance (IPD) suitable most viewers. We added 1) a 3D-printed slider for the precise positioning of the prisms. 2) an eye piece with separate viewing ports to ensure a fixed distance between the eyes and the prisms.The IPD of each observer was used to adjust the distance between the centers of the haploscope prisms. Observers used a program developed in MATLAB to adjust the degree of horizontal displacement of left/right images on the screen.We compared results with the original haploscope and with the improved apparatus. Stimuli included random-dot stereograms (RDS), computer-generated objects and pictures of human faces. In the RDS condition, the task was to decide whether the presented shape was located in front or behind the background. In the 3D object and the face conditions, the task was to report whether the object/face was convex, concave or flat. Results: Data indicates significant improvement in accuracy with RDS images with the customized setup. Surprisingly, even after the improvement, not all viewers were virtually 100% correct in perceiving convex faces as convex, whereas they were all virtually 100% correct with physical masks (Keane et al. 2013). Conclusion: Setting up the haploscope to accommodate the viewer's unique IPD distance improves accuracy of depth perception. Despite the improvement, performance with stereoscopic images is still inferior to that with physical objects.

53.4080 Watching 2-D movies improves stereoacuity Bart Farell[1](b-farell@syr.edu), Cherlyn Ng[1], Mimi Lu[2]; [1]Institute for Sensory Research, Syracuse University, [2]Fayetteville-Manlius High School

Drawings, paintings, photos, videos, and movies are acceptable, indeed sought after, 2-D stand-ins for 3-D scenes and make up a large and growing fraction of the total visual input of many modern humans. Yet they severely distort the visual signals available in the 3-D version. Binocular disparities, monocular occlusions, blur, motion parallax, and perspective are absent or altered. Still, viewers of these images are seldom bothered, or even notice, these distortions, implying an adaptation to the cues available in 2-D visual media. In order to assess this adaptation through its aftereffects, we used commercial movies in 2-D, 3-D, and reversed-stereo versions as adapting stimuli. Of particular interest were effects due to the absence of disparity cues and the inconsistency between perspective and disparity. We measured observers' sensitivity to depth using three tasks: (1) discrimination and (2) adjustment of the relative stereo-depth of two vertical lines in the presence of irrelevant depth-from-perspective cues, and (3) depth discrimination of random-dot stereograms. In discrimination tasks, observers reported the line or random-dot interval having the nearer depth value. In the adjustment procedure, observers set a perceptual depth match between the lines. Stereoacuity was higher after watching 2-D movies for all but one observer (total: 5) and all tasks. Perspective had an irregular effect across observers. Regular and reversed-depth 3-D movies did not affect stereoacuity or depth from perspective. Reading text under movie-viewing conditions improved stereoacuity, the same as movie-watching. We conclude that depth cue conflict is not essential for the improvement in stereo performance. Adaptation to near-zero disparities appears sufficient to raise sensitivity to subsequent non-zero disparities, with recovery to baseline extending over a period of approximately 30 minutes post-adaptation.

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53.4081 Position matching between the eyes in strabismus Zahra Hussain[1](zahra.hussain@aub.edu.lb), Andrew Astle[2], Ben Webb[2], Paul McGraw[2]; [1]American University of Beirut, [2]University of Nottingham

Misalignment of the visual axes in strabismus disrupts retinal correspondence and therefore fusion. Fusional status is usually assessed centrally where the perceptual consequences of misalignment are most prominent, but the periphery is also affected. We used a dichoptic spatial mapping procedure to measure the perceived horizontal offset of a stimulus presented to the deviating eye of a large and heterogeneous group of strabismic observers (N = 32), at thirty-two positions in the visual field. The free-localization task required observers to move a response probe presented to the deviating eye, to a position diagonally opposite a reference probe presented to the fixing eye. The reference and response probes were placed in opposite hemifields to reduce luminance cues and interocular suppression. Observers with normal binocular vision were also tested (N = 20), with the reference and response probes randomized between the eyes. Perceived offsets were quantified at each location to produce a spatial map for each observer; spatial maps across observers were examined for patterns associated with the direction and magnitude of ocular deviation. We found a reliable and striking non-uniformity in the magnitude of perceived offset across the visual field of strabismic subjects: at 1 deg, the offset was larger in the visual field in the direction of ocular deviation, than in the visual field against the direction of deviation. This effect was reversed at 7 deg, and was absent in individuals with negligible mean perceived offset. Whereas offset direction was consistent with the direction of ocular deviation, offset magnitude was uncorrelated with the objective angle of deviation indicating the presence of anomalous retinal correspondence in a number of observers. The asymmetric visual field distortion may partly be accounted for by retinal geometry and interocular suppression, but additional cortical adaptations must contribute to the overall pattern observed.

53.4082 Using perceptual learning in VR to train stereo-anomalous observers to rely on disparity cues Angelica Godinez[1](angelica_godinez@berkeley.edu), Santiago González[2], Dennis Levi[1]; [1]School of Optometry, University of California, Berkeley, [2]Construcción e ingeniería de fabricación, Universidad de Oviedo

Stereopsis plays an important role in everyday visuomotor tasks. However, abnormal visual experience during development caused by amblyopia and/or strabismus may result in reduced or absent stereopsis. While perceptual learning (PL) can improve stereopsis in adults with abnormal binocular vision, it requires many trials (Ding & Levi, 2011). Thus, attention and compliance may limit the utility of PL. Game principles can be used to tackle both challenges. Indeed, several studies have reported the benefits

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of using video games to treat amblyopia. Recently, the introduction of consumer Virtual Reality (VR) devices has opened the opportunity to design new PL therapies. Our aim was to test whether VR can be used to train stereo-anomalous observers to rely on disparity cues. We designed two games to train stereovision using a VR headset. One game required players to launch a dart when a dartboard moving in depth, is in the same depth plane as the dart. The other game required the player to destroy the nearest of several ghosts. Importantly, initially the games provided multiple cues for judging depth (shadows, perspective, motion parallax, and disparity). As players progressed we selectively removed cues (shadows, perspective and motion parallax), finally leaving only disparity cues. Play started with a dichoptic calibration, where strabismic angles were corrected and the input to the two eyes was perceptually balanced by reducing the luminance/contrast to the dominant eye, creating a single image and reducing suppression. High contrast binocular frames were used to facilitate binocular fusion. Our preliminary results show that most of the stereo deficient players improved in the game, and several showed transfer to both clinical (Randot®) and dynamic Random Dot Stereoacuity tests (Ding & Levi, 2011). We conclude that consumer VR devices may provide a new tool for the recovery of stereopsis in adults with abnormal binocular vision.

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53.4083 Exploring the relationship between the visual acuity interocular differences and stereopsis in strabismus and amblyopia patients

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By measuring the visual acuity interocular differences and functional deficits of fine stereopsis in amblyopia and strabismus & amblyopia patients with coarse stereopsis to study the relationship between acuity interocular differences, stereopsis and disease patterns, from the perspective of spatial resolution, binocular integration and interaction. 233 patients with amblyopia and strabismus & amblyopia , age around 4 to 17 years old, participated in the present study. The performances of visual functions in patients under various conditions were measured by using random-dot-coarse and –fine stereopsis model. According to the grade separation, stereopsis was classified into 2 types: type□-with both coarse and fine stereopsis, type □ -with coarse but without fine stereopsis. There are 105 amblyopia and 19 strabismus & amblyopia in type□, while 80 amblyopia and 39 strabismus & amblyopia in type □. There is no significant correlation in the visual acuity interocular differences (vIODs) of amblyopia patients between type□and □□t=0.068□. However, vIODs of strabismus & amblyopia patients in type I and II showed significant correlation □t=0.011□,with vIODs mean of 0.10,0.24. There is no correlation in vIODs between strabismus & amblyopia and amblyopia patients of type□□t=0.258□nor type □ □t=0.496□. The stereopsis and binocular vIODs in amblyopia classified above showed no correlations, while there is significant correlations between vIODs and the existence of fine stereopsis in strabismus & amblyopia. Mean vIODs of type□is 0.14 less than that of type □. There is no relevance between binocular integration and spatial resolution differences on stereopsis level in amblyopia, in which deficits of binocular channel noise processing is dominate. Strabismus & amblyopia has binocular visual functioning deficits due to the poor binocular central control ability, combined with binocular channel noise processing deficits that directly influences IODs of interocular spatial resolution.

53.4084 The GENUA PESTO Database - GENoa hUman Active fixation database: PEripersonal space STereoscopic images and grOund truth disparity

Agostino Gibaldi[1,2](agostino.gibaldi@unige.it), Andrea Canessa[1], Manuela Chessa[1], Marco Fato[1], Fabio Solari[1], Silvio Sabatini[1]; [1]DIBRIS - University of Genova, [2]UC Berkeley

The statistics of natural environments is an effective source of information to infer the characteristics of the neural mechanisms underlying the encoding and processing of visual information, from orientation and contrast, to depth and retinal disparity. Specifically for retinal disparity, the available databases usually provide stereoscopic image pairs that are strictly built from computer vision perspective. The cameras are positioned with parallel optical axes, an eye posture seldom assumed by the visual system, and they mainly focus on relatively distant scenes, i.e. where binocular stereopsis is less relevant to depth perception. In the present work, we developed a large dataset of stereoscopic images that is: 1) conceived to mimic the actual posture of the binocular visual system, i.e. considering eye vergence and cyclotorsion, and 2) belongs to the peripersonal space, i.e. where depth perception actually relies on stereopsis. The proposed approach relies on 3D virtual models of natural scenes, characterized by accurate depth information and natural textures. These models have been used in a graphic stereo vision simulator that mimics the natural viewing posture of the human visual system at different gaze directions. The resulting dataset is characterized by high spatial accuracy, realistic color texture, groundtruth disparity maps, occlusions and depth edges. This would make the dataset a powerful tool to investigate the relevance of depth and disparity information over the visual system, usable in different research fields. In psychophysics and neuroscience experiments it provides an invaluable means to create fully controlled and accurate experimental setups. Exemplifying, in spatial vision and eye movement studies, the ground-truth data allows for a quantitative characterization of human performance. In neural modeling, the large number of stereoscopic pairs allows for statistical predictions about the required computational resources, as well as the possible strategies functional to an efficient encoding of disparity information.

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53.4085 Efficient encoding of binocular disparity predicts sensitivity to depth differences

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The distribution of the preferred disparities of binocularly-tuned neurons is highly non-uniform, with many more neurons tuned to small disparities close to the horopter. These neurons have been classified as tuned-excitatory, tuned-inhibitory, near and far (Poggio 1995), depending on the way that their responses vary with disparity. Near and far cells respond to a broad range of crossed or uncrossed disparities, respectively, while the responses of tuned excitatory or inhibitory cells are modulated by disparities within a narrow range. This distribution of disparity tuning is optimised for the efficient coding of the disparities found in natural scenes, which are strongly peaked around zero (Liu, Bovik and Cormack, 2008; Sprague, Cooper, Tošić and Banks, 2015). We assessed whether (i) this efficient encoding of binocular information might account for human sensitivity to disparity differences and (ii) whether this encoding adapts to short-term changes in the distribution of disparities. Test stimuli were random-dot stereograms in which one patch was shifted forwards in depth from a pedestal value, and the other shifted backwards. We used a 2AFC procedure to measure sensitivity to depth differences as a function of the pedestal value. Disparity thresholds increased with pedestal disparity, consistent with the prediction of an efficient coding model. To assess whether this sensitivity adapts to short-term changes in the distribution of disparities, observers were then exposed to a small (0 arc min) or large (±20 arc min) range of disparities. Sensitivity was measured again after adaptation. Thresholds were not affected by short-term adaptation. These results show that both the physiological encoding of disparity, and observer's sensitivity to depth differences, are consistent with an efficient coding of the distribution of disparities found in the natural environment. Finally, disparity encoding does not appear to adapt to short-term changes to the distribution of disparities.

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53.4086 Predicting effects of natural depth variation on binocular disparity estimation

Arvind Iyer[1](arvindiy@sas.upenn.edu), Johannes Burge[1]; [1]Department of Psychology, University of Pennsylvania

Reliable estimation of binocular disparity is fundamental to our ability to estimate the relative depth of objects in natural scenes. Classical laboratory stimuli are not representative of the stimuli that disparity-processing mechanisms encounter in natural scenes. Here, we examine the impact of natural disparity variation (arising from natural depth variation) on disparity detection performance. First, we obtained a database of calibrated natural stereo-images with precisely co-registered laser measurements of groundtruth distance at each pixel. Second, we developed a procedure that uses the groundtruth distance data and has arcsec precision, to sam-

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ple 50000 stereo-patches centered on binocular corresponding points. For each stereo-patch, we computed a ground-truth map of local absolute disparities in the foveal region. The disparity contrast (root-mean square contrast of the disparity map) quantifies local disparity variation around fixation. High disparity contrast hampers precise estimation of fixational disparity. An ideal observer for disparity estimation in natural scenes, and a local windowed cross-correlation routine both yield disparity estimates where reliability decreases with increases in disparity contrast. Thus, disparity contrast predicts the reliability of disparity estimates. Information about estimate reliability can aid subsequent visual processing and perceptual decisions. However, just like with fixational disparity, the visual system has no direct access to groundtruth disparity contrast, and must instead estimate it from the binocular luminance images. Interestingly, two simple statistics, (i) the binocular luminance difference, and (ii) the root-mean-square contrast of the binocular difference image (left-eye minus right-eye image) are both predictors of disparity contrast. The difference image contrast is a particularly strong predictor. The natural scene statistics indicate that the contributions of these two predictors to estimates of disparity contrast are multiplicative and separable. These findings suggest multiple computational and psychophysical investigations of mechanisms for estimating local disparity variation, and assessing its impact on human disparity estimation performance in natural scenes.

Perceptual Learning: Models and neural mechanisms

Tuesday, May 23, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.4087 The effects of cholinergic enhancement and consolidation duration on perceptual learning of texture discrimination

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Visual perceptual learning (VPL) is an enduring improvement in performance following training on a visual task. VPL of texture discrimination is retinotopically specific, and consolidation of this learning is enhanced by rapid eye movement (REM) sleep (Mednick et al., 2003). Interestingly, endogenous acetylcholine (ACh) release is elevated during REM sleep. Cholinergic enhancement increases the magnitude and specificity of VPL for motion direction discrimination, and this benefit is maintained for at least several months after the end of training and drug administration (Rokem & Silver, 2010; 2013). Here, we conducted a double-blind crossover study to determine if cholinergic enhancement would facilitate texture discrimination learning and, if so, at what time scale. Each subject participated in two training sessions in which they were administered either 5 mg of donepezil, which prolongs the signaling of endogenous ACh, or placebo. These training sessions (experimental days 1 & 15) were spaced two weeks apart to allow for complete elimination of the drug (if present). Learning was assessed one day after each training session (short-term: days 2 & 16) and again either 2 or 4 weeks later (long-term: day 29). We also examined specificity of VPL by measuring performance in an untrained visual field location on day 29. Significant VPL was evident in both short- and long-term testing sessions. However, we found no significant effect of training with donepezil compared to placebo for either short- or long-term VPL. Unexpectedly, we found that regardless of drug condition, significantly more VPL was observed in visual field locations that were trained 4 weeks prior compared to those trained 2 weeks prior. This suggests that consolidation of VPL can continue for as long as a few weeks after the end of training.

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53.4088 Alertness may explain how reward evokes visual perceptual learning

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A number of studies have demonstrated that reward evokes task-irrelevant perceptual learning (Seitz et al, 2009). However, the underlying mechanisms are still unknown. There are at least 2 possible hypotheses for the mechanisms: a reinforcement hypothesis or an alertness hypothesis. A critical factor to dissociate the two hypotheses is the timing between the reward signal and the paired visual stimuli. If the reinforcement hypothesis is true, reward needs to follow the rule of contiguity. Thus, learning should occur only for a visual stimulus presented after the reward is given. On the other hand, according to the alertness hypothesis, reward enhances alertness to a stimulus presented temporally close to reward presentation, irrespective of whether it is presented before or after the stimulus. Thus, if the alertness hypothesis is the case, learning should occur for a visual stimulus presented both before and after the reward is given. To test which hypothesis is true, we manipulated the timing between an exposed visual stimulus and reward. Prior to each of 12 days' training sessions, subjects underwent 5 hours of fasting. In training, a sequence of two orientations was exposed in a random order to the trained eye, whereas dynamic color patches were presented to the other eye to perceptually erase the orientations in the other eye (CFS paradigm). One of the orientations was paired with the reward presented 400 ms prior to the stimulus onset, and the other orientation paired with reward delivered 400 ms after the stimulus onset. Subjects' sensitivity to the 2 orientations was tested by a detection task in both eyes before and after training. Subjects showed significant improvement in the trained eye for both reward timings. There was no improvement in the untrained eye. These results are consistent with the alertness hypothesis for task-irrelevant perceptual learning in association with reward.

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53.4089 Practice changes the hippocampal-neocortical communication

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Visual learning involves not only adjustments in local functionality but also dynamic reshaping of connectivity among cortical areas in the brain network. Reshaping of connectivity is needed to provide task-relevant context, as mediated by the hippocampus, and to provide reinforcement signals, as mediated by the anterior cingulate cortex (ACC). Here we demonstrated a practice effect in hippocampus and ACC, which happened at the very initial stage of learning. Subjects were asked to detect a pause in the flickering of the visual stimuli in the right visual field. Whole-brain BOLD signals were measured with fMRI on two different days. Using the region activated by the visual stimuli in V1 as the seed, we calculated its functional connectivity with hippocampus and ACC, with the task-related activity regressed out. The connectivities among V1, hippocampus and ACC showed distinct changes across runs during the first day. While the connectivity between V1 and hippocampus decreased, the connectivity between V1 and ACC increased. The connectivity between hippocampus and ACC also increased. These effects were only observed on the first day. No change in the connectivity among these areas was observed on the second day. Connectivities between V1 and extrastriate visual areas V2-V4 remained constant throughout the experiment. The dynamic disengagement of hippocampus and engagement of ACC to V1 reflect the evolving needs of contextual information and task monitoring. It is also consistent with the view that hippocampus supports rapid learning and gradual transfer of learning to the neocortex (Kumaran et al., 2016).

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53.4090 Did you see that? Examining whether statistical learning can elicit category-specific EEG activity in the absence of visual stimuli

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It is well-established that the visual system can extract statistical regularities in transitional probabilities between objects in a serial stream, making statistical learning paradigms well-suited to studying the neural mechanisms of learning. For example, previous fMRI studies have revealed that anticipating a stimulus that is predicted by statistical regularities in a sequence can produce item-specific activity even when the anticipated stimulus itself is not shown (Kok, Failing, & de Lange, 2014; Puri, Wojciulik, & Ranganath,

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2009). However, little is known about the time course of these anticipatory effects at temporal resolutions finer than that afforded by fMRI. Thus, the present study used EEG with a statistical learning paradigm in which auditory syllables were paired with either faces or objects in an initial acquisition phase, such that certain syllables were always paired with specific faces, certain syllables were always paired with specific objects, and a subset of syllables were not assigned to any picture. Following acquisition, participants took part in a second session that was identical to acquisition except that 25% of (anticipated) face and object pictures were randomly omitted. The critical questions are whether anticipated face/object pictures still produce category-specific EEG activity (e.g., the face-specific N170 ERP) when they are unexpectedly omitted, and at what point in the EEG time course such category-specific activity emerges. Critically, in the absence of anticipated stimuli, the wave form elicited in response to the paired associate closely resembles the expected wave form when the anticipated stimulus is present. The results shed new light on the neural mechanisms underlying visual statistical learning and provide insight regarding the extent to which category-specific anticipatory activity is intentional versus automatic.

Acknowledgement: This research was supported by an RII Track-2 FEC grant (Award #1632849)

53.4091 **Orientation discrimination training refines the stimulus comparison, rather than the perceptual encoding process in the primary visual cortex** Ke Jia[1,2,3,4](jiake9728@163.com), Sheng Li[1,2,3,4]; [1]School of Psychological and Cognitive Sciences, Peking University, [2]Beijing Key Laboratory of Behavior and Mental Health, Peking University, [3]Key Laboratory of Machine Perception (Ministry of Education), Peking University, [4]PKU-IDG/McGovern Institute for Brain Research, Peking University

The neural underpinning of discrimination training remains highly controversial. While physiological studies found little, if any, evidence for the training effect in sensory cortex (Law & Gold, 2008), such effects were pronounced in fMRI studies. The apparent difference in results between the two approaches could be due to the sluggish nature of the fMRI signals, which confounded perception with other cognitive processes involved in the discrimination task, such as stimulus comparison. Here, we adopted a long-delay orientation discrimination task to decouple the perceptual encoding of stimulus from the process of stimulus comparison. We trained participants with a short-delay (ISI, 0.6 s) orientation discrimination task for six days (peripheral, 6.5°, at the top left / lower right corner; orientation, 45° / 155°), whereas testing the training effect with the long-delay orientation discrimination task (ISI, 11.8 s, along both the trained and untrained orientation) in the scanner before, after, and ~10 days after the training. Participants' performance improved gradually over the time courses of training. The training effect preserved when measured with the long-delay discrimination task both immediately and 10 days after the training, and was accompanied by an enhanced brain activity specific to the trained orientation in the primary visual cortex. Importantly, the enhanced brain activation was only evident during the processing of the second stimulus in the trial sequence and disappeared ten days after the training. These results suggest that the pronounced changes of brain activity in the primary visual cortex may be related to the process of stimulus comparison, rather than the perceptual encoding of the stimulus.

Acknowledgement: the National Natural Science Foundation of China (31230029, 31271081).

53.4092 **Visual Perceptual Learning of Faces modifies a physiological abnormality in patients with Body Dysmorphic Disorder to a normal level** Qingleng Tan[1](qingleng_tan@brown.edu), Kazuhisa Shibata[2], Katharine philips[3], David Sheinberg[4], Yuka Sasaki[1], Takeo Watanabe[1]; [1]Department of Cognitive, Linguistic and Psychological Sciences, Brown Univeristy , [2]Department of Psychology, Graduate School of Environmental Studies,Nagoya University, [3]Rhode Island Hospital and the Department of Psychiatry and Human Behavior, Warren Alpert Medical School of Brown University, [4]Department of Neuroscience, Brown University

Body dysmorphic disorder (BDD) is characterized by distressing or impairing preoccupation with imagined or slight defects in patients' own appearance, especially faces. Previous studies have suggested that distortion of holistic visual processing is involved in BDD. This raises the possibility that training particularly on low spatial-frequency components of images would at least partially reduce the symptoms of BDD. Here, we tested whether visual processing of low spatial-frequency with BDD patients is different from normal controls either before or after training on low spatial-frequency components of images of faces. Individuals with BDD (n=9) as well as controls (n=10) were trained for 6 days on a two-interval forced choice task. Participants underwent fMRI sessions before and after training while performing the two-interval forced choice task. Performance on faces and houses in low (< 10 cycle per stimulus) and high (> 15 cycle per stimulus) spatial-frequency bands was assessed during scans. We found no qualitative difference in performance between the patients and controls either before or after training: training made both groups selectively increase their sensitivity to low spatial-frequency faces (low spatial-frequency face: $p< 0.01$, other conditions: $p>0.1$). However, before training, there was a significant difference in brain processing: In normal controls, fMRI responses in FFA were stronger in the right than left hemispheres. The degree of the right dominance was smaller in BDD patients than controls. After training, however, BDD patients showed increased right dominance while normal controls showed reduced right dominance, so that the difference in the degree of right dominance between the two groups was washed out. These patterns were not observed in early visual areas or in the parahippocampal place area. We conclude that the neural mechanisms of visual processing and plasticity are different between BDD patients and normal controls, although no significant behavioral difference is shown.

Acknowledgement: NIH R01EY019466 Systematic Psychophysical Investigation of Visual Learning

53.4093 **Task-Irrelevant Motion-Training Improves Word Decoding in Reading Disabled Participants** Steven Holloway[1](srh@asu.edu), José Náñez, Sr[1], Michael McBeath[2]; [1]School of Social and Behavioral Sciences, Arizona State University, [2]Department of Psychology, Arizona State University

The basic phenomenon of task-irrelevant perceptual learning is that near-visual-threshold stimuli that are irrelevant to a central task can be learned due to their consistent and concurrent presentation during task performance. The temporal occurrence of central concentration paired with near-threshold stimuli increases perceptual sensitivity to the unattended, near-threshold stimulus. Research has implicated the central dorsal stream, specifically the V3a to the MT, as being at least partially responsible for one aspect of reading, namely, word decoding. Early research showed that perceptual thresholds of flicker processing are significantly lower in people with a reading disability. Interestingly, this is the same region of the brain that is responsible for processing motion, contrast, and flicker. Further, research has shown that task-irrelevant learning of near-threshold motion increases flicker perception. The present study employed a task-irrelevant motion-training paradigm consisting of a paired-shapes visual-recognition task, using colored polygon-shaped targets as salient, attended focal stimuli, with the goal of eliciting increased perceptual sensitivity to motion. It was hypothesized that improvements in motion detection would result in enhanced flicker perception and word-decoding ability in a reading disabled population of college-aged students. The study included pre-test, training, and post-test phases. Perceptual sensitivity changes were evaluated by comparing pre-test to post-test performances. Here, we show that reading disabled participants who were exposed to near-threshold motion-training improved in sensitivity in all measures. Control participants who were exposed to near-threshold tone changes in lieu of motion showed perceptual sensitivity improvements in tone discrimination but not motion detection, flicker perception, or word decoding. These findings demonstrate that a psychophysical visual learning paradigm may be employed to mediate some effects of reading difficulties. If our future research shows that improved performance on the current tasks generalizes to improve reading ability, we plan to deploy our paradigm as a computer-game-based intervention for reading disabled individuals.

53.4094 **Sequential Decision Making: From Vision to Decisions and Back** He Xu[1](he.xu@epfl.ch), Michael Herzog[2]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland

Usually, visual processing precedes decision making. Here, we show that activity of the visual cortex is strongly modulated by feedback in sequential decision making tasks. Observers were presented with a clip art image, such as a boat, and 2, 3, or 4 disks below the image. Clicking on a disk led to the presentation of the next image, which could be the same image (No reward), a new image (Intermediate reward), or the goal image (Full reward). Observers clicked on the disks until the goal was found. In addition, we recorded 128 channel EEG. For the three feedback conditions, we found strong differences in the amplitudes of occipital electrodes at the P2 (150-275ms) and P3 (250-500ms). Inverse solutions in the frequency domain during these periods, computed by sLoreta, showed that the visual cortex is less activated in the theta band (4-7Hz) and more strongly activated in the beta band (15-30Hz) when comparing the Full with the No reward condition. There were no differences between these conditions in the alpha (7-10Hz) and the gamma band (above 30Hz). In the anterior cingulate cortex (ACC), the Full reward condition leads to higher activation than the No reward conditions in all frequency bands. Since the modulation occurs well beyond early visual processing, we suggest that top-down activation from the frontal areas, including the ACC, changes visual processing of the images depending on the specific feedback obtained. Our findings are well in line with neurophysiological work showing that beta activity in the visual cortex of cat is bursting if there is a rewarding cue. As a speculation, we propose that the visual cortex and the ACC communicate in these types of tasks mainly in the beta frequency regime.

Acknowledgement: Learning from Delayed and Sparse Feedback, Project Number: CRSII2_147636,Swiss National Science Foundation (SNFS)

53.4095 **Perceptual learning in n-alternative forced choice with response and accuracy feedback, and a reweighting model.** Jiajuan Liu[1](jiajuanl@gmail.com), Barbara Dosher[1], Zhong-Lin Lu[2]; [1]Department of Cognitive Sciences, University of California, Irvine, [2]Department of Psychology, Ohio State University

Visual perceptual learning has, with few exceptions, been investigated in the context of two-alternative forced (2AFC) choice tasks. In this study, we trained observers with an 8AFC orientation task in external noise with two forms of feedback: response feedback (RF) in which feedback indicates the correct response and accuracy feedback (AF) in which feedback indicates whether the response is accurate. Perceptual learning in such tasks may more closely approximate the complexity of real world tasks. We elaborated and extended a computational model of nAFC tasks based on the Integrated Reweighting Theory (IRT, Dosher et al., 2013) by using multiple decision units and a max rule. Generally, the elaborated IRT predicts better performance for RF than AF feedback under a range of conditions. Performance was measured over the course of practice at three contrast levels (0.3, 0.6, 1.0) for Gabors of eight orientations separated by 22.5°. Performance measures included percent correct, weighted k (partial credit for adjacent responses), and confusion matrices. Four of five observers receiving RF and three of five observers receiving AF showed significant learning (percent correct, k) over eight sessions of 960 trials each. Two additional AF observers who appeared not to learn dropped after a few sessions. Subsequent training of a few observers without external noise provided an estimate of asymptotic accuracy. Two AF observers who failed to learn showed lower asymptotic noiseless accuracies, suggesting either broader bandwidth of orientation tuning or higher levels of internal noise. The confusion matrices provide further diagnostic information about stereotyped response biases from broad errors clustering around the correct diagonal, and also show how the weights on evidence grow during learning. These results are consistent with the predictions from the nAFC IRT model that performance is improved more with RF than AF.

Acknowledgement: NEI

53.4096 **Unsupervised learning of repeating patterns using a novel STDP based algorithm** Simon Thorpe[1](simon.thorpe@cerco.ups-tlse.fr), Amirreza Yousefzadeh[2], Jacob Martin[1], Timothée Masquelier[1]; [1]CerCo, CNRS, [2]Instituto Microelectronica de Sevilla, University of Sevilla

Computational vision systems that are trained with deep learning have recently matched human performance (Hinton et al). However, while deep learning typically requires tens or hundreds of thousands of labelled examples, humans can learn a task or stimulus with only a few repetitions. For example, a 2015 study by Andrillon et al. showed that human listeners can learn complicated random auditory noises after only a few repetitions, with each repetition invoking a larger and larger EEG activity than the previous. In addition, a 2015 study by Martin et al. showed that only 10 minutes of visual experience of a novel object class was required to change early EEG potentials, improve saccadic reaction times, and increase saccade accuracies for the particular object trained. How might such ultra-rapid learning actually be accomplished by the cortex? Here, we propose a simple unsupervised neural model based on spike timing dependent plasticity, which learns spatiotemporal patterns in visual or auditory stimuli with only a few repetitions. The model is attractive for applications because it is simple enough to allow the simulation of very large numbers of cortical neurons in real time. Theoretically, the model provides a plausible example of how the brain may accomplish rapid learning of repeating visual or auditory patterns using only a few examples.

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Spatial Vision: Texture and natural image statistics

Tuesday, May 23, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.4097 **Children's use of visual summary-statistics for material recognition** Benjamin Balas[1](benjamin.balas@ndsu.edu), Jamie Schmidt[1]; [1]Psychology Department, North Dakota State University

A growing body of work describes adult material recognition and perception,but the development of material perception during childhood has been largely ignored. Presently, our goal was to investigate how material perception changes during middle childhood, both with regard to overall abilities as a function of material category and also with regard to the use of summary-statistics for material recognition relative to higher-order/global appearance descriptors. We carried out two experiments: A material categorization task (Experiment 1) and a material matching task (Experiment 2). For both tasks, we recruited children aged 5-10 years old (N=40) and compared their performance to adults (N=20). In Experiment 1, participants performed a 4AFC material categorization judgment using natural images of metal, stone, water, and wood, and synthetic images created from these using the Portilla-Simoncelli texture synthesis algorithm. In Experiment 2, we used these stimuli to implement a material matching task. Here, participants were presented with a sample image on each trial and indicated which of two test images depicted the same material. In both experiments, the synthetic appearance condition allowed us to examine how performance was affected by representing material appearance using only the Portilla-Simoncelli summary-statistics. In Experiment 1, we observed a significant interaction between age, material category, and appearance ($p = 0.004$): Observers of all ages were less accurate with synthetic textures, but young children (5-7 years old) were disproportionately worse, especially when categorizing wood and water. In Experiment 2 (which did not require labeling textures), we observed a slightly different outcome: Water was again disproportionately impacted by texture synthesis, but this did not interact with age. We conclude that the ability to use summary-statistics for material recognition develops during middle childhood, and that different material categories depend differentially on such descriptors, leading to asynchronous development of material perception across distinct material classes.

Acknowledgement: NEI R15 EY024375-01

53.4098 **A parametric texture model based on deep convolutional features closely matches texture appearance for humans** Christina Funke[1,2,9](christina.funke@web.de), Thomas Wallis[1,2,9], Alexander Ecker[1,2,3], Leon Gatys[1,2], Felix Wichmann[2,4,5,6], Matthias Bethge[1,2,7,8]; [1]Werner Reichardt Center for Integrative Neuroscience, Eberhard Karls Universität Tübingen, [2]Bernstein Center for Computational Neuroscience, Tübingen, [3]Department of Neuroscience, Baylor College of Medicine, Houston, TX, USA, [4]Neural Information Processing Group, [5]Faculty of Science, Eberhard Karls Universität, [6]Institute for Intelligent Systems, Empirical Inference Department, Tübingen, [7]Theoretical Physics, Eberhard Karls Universität Tübingen, [8]Max Planck Institute for Biological Cybernetics, Tübingen, [9]Equal first author

Much of our visual environment consists of texture—"stuff" like cloth, bark or gravel as distinct from "things" like dresses, trees or paths—and we humans are adept at perceiving textures and their subtle variation. How does our visual system achieve this feat? Here we psychophysically evaluate a new parameteric model of texture appearance (the CNN texture

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model; Gatys et al., 2015) that is based on the features encoded by a deep convolutional neural network (deep CNN) trained to recognise objects in images (the VGG-19; Simonyan and Zisserman, 2015). By cumulatively matching the correlations of deep features up to a given layer (using up to five convolutional layers) we were able to evaluate models of increasing complexity. We used a three-alternative spatial oddity task to test whether model-generated textures could be discriminated from original natural textures under two viewing conditions: when test patches were briefly presented to the parafovea ("single fixation") and when observers were able to make eye movements to all three patches ("inspection"). For 9 of the 12 source textures we tested, the models using more than three layers produced images that were indiscriminable from the originals even under foveal inspection. The venerable parameteric texture model of Portilla and Simoncelli (Portilla and Simoncelli, 2000) was also able to match the appearance of these textures in the single fixation condition, but not under inspection. Of the three source textures our model could not match, two contain strong periodicities. In a second experiment, we found that matching the power spectrum in addition to the deep features used above (Liu et al., 2016) greatly improved matches for these two textures. These results suggest that the features learned by deep CNNs encode statistical regularities of natural scenes that capture important aspects of material perception in humans.

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53.4099 Upscaling and Combing Artifact Prediction on Motion Pictures Using Convolutional Networks

Todd Goodall[1](tgoodall@utexas.edu), Alan Bovik[1]; [1]Department of Electrical and Computer Engineering, University of Texas at Austin

Methods for detecting visual artifacts in digital motion pictures are usually limited to specialized algorithms, each designed to deal with a single type of artifact. Content providers and video archivists both asses the visual quality of the videos in their collections, which requires artifact identification and localization. Effective detection solutions do not exist for all visual artifact types, especially as evolving media introduces new artifacts. As such, development of a general approach to motion picture quality assessment would be a significant boon for both producers and consumers of motion picture content. We have developed a single model, based on basic principles of visual perception and models of naturalistic pictures, which can be trained to produce a highly accurate detector of either upscaling or combing artifacts in motion pictures without any need for a reference signal. This model uses a shallow convolutional neural network to identify distorted locations in any sized input image or video. This local detection performed globally makes it possible to produce a dense detection map, which can then be used either to make a final overall prediction of the perceptual quality of the image or video. Using large (>100,000 samples) class-balanced test datasets, we observed an F1 score of 0.995 when distinguishing up-scaled images from natural images, and an F1 score of 0.99 when distinguishing combed video frames from pristine video frames. The model yields state-of-the-art prediction power on upscaling and combing artifacts that occur in digital motion pictures. The areas of distortion need not be known a priori, since it is learned using only global image/video labels. We envision that this general framework for motion picture artifact detection will provide the basis for powerful tools that will prove useful in the motion picture post-production and distribution industries.

Acknowledgement: Netflix

53.4100 Natural image statistics as a function of dynamic range

Antoine Grimaldi[1](antoine.grimaldi@upf.edu), David Kane[1], Marcelo Bertalmío[1]; [1]DTIC, Universitat Pompeu Fabra

The statistics of real world images have been extensively investigated, in virtually all cases using low dynamic range (LDR) image databases. The few studies that have considered high dynamic range (HDR) images have performed statistical analysis over illumination maps with HDR from different sets (Dror et al. 2001) or have examined the difference between images captured with HDR techniques against those taken with single-exposure LDR photography (Pouli et al. 2010). In contrast, in this study we investigate the impact of dynamic range upon the statistics of equally created natural images. To do so we consider the HDR database SYNS (Adams et al. 2016). For the distribution of intensity, we observe that the standard deviation of the luminance histograms increases noticeably with dynamic range. Concerning the power spectrum and in accordance with previous findings (Dror et al. 2001), we observe that as the dynamic range increases the 1/f power law rule becomes substantially inaccurate, meaning that HDR images are not scale invariant. We show that a second-order polynomial model is a better fit than a linear model for the power spectrum in log-log axis. A model of the point-spread function of the eye (considering light scattering, pupil size, etc.) has been applied to the datasets creating a reduction of the dynamic range, but the statistical differences between HDR and LDR images persist and further study needs to be performed on this subject. Future avenues of research include utilizing computer generated images, with access to the exact reflectance and illumination distributions and the possibility to generate very large databases with ease, that will help performing more significant statistical analysis.

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53.4102 Effect of temporal modulations of dynamic inducer on tilt illusion

Sae Kaneko[1,2,3](sakaneko@ucsd.edu), Stuart Anstis[3], Ichiro Kuriki[2]; [1]Japan Society for the Promotion of Science, [2]Research Institute of Electrical Communication, [3]University of California, San Diego

De Valois et al (1986) examined the temporal frequency properties of simultaneous contrasts when an inducing surround varied sinusoidally in luminance/color. They found that illusory modulation was induced into a static test stimulus only at rates below 2-3 Hz. They concluded the induction was a sluggish, possibly cortical process. However, recent studies showed brightness and color inductions can be fast (e.g. Blakeslee & McCourt, 2008) and stronger in flashes than steadily presented stimuli (Kaneko & Murakami, 2012). Previously, we also showed that strong tilt illusion can be seen in flashed stimuli (VSS 2016). We now measured the temporal frequency properties of tilt illusion with dynamic inducers, using a method of adjustment. A vertical test grating was centered in a larger grating pattern, the inducer (both 1.5 cycles-per-degree). The orientation of the inducer modulated back and forth sinusoidally at 0.5-8.3 Hz from -15° to +15°. A comparison grating was presented aside and its orientation was modulated in sync with the inducer, but in opposite phase. Subjects adjusted the amplitude of its modulation to match the orientations induced into the test. We used two types of modulation; continuous condition, where the inducer and the test were always visible, and intermittent condition, where the inducer and the test were flashed for 1 frame (10 ms) at the maximum tilts of the inducer. For continuous condition, the illusion seen at 0.5 Hz weakened as the modulation rate became higher and almost disappeared at 2-3 Hz, as in De Valois et al (1986). For intermittent condition, the tilt illusion persisted up to a higher rate (> 4 Hz). The difference was not explained by assuming that the induction system was a simple low-pass linear filter. Instead, we suggest the involvement of nonlinear mechanism(s).

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53.4103 Representing color ensembles: Mapping internal probability density functions with attentional priming

Arni Kristjansson[1](ak@hi.is), Gianluca Campana[2], Andrey Chetverikov[1]; [1]School of Health Sciences - University of Iceland, [2]Department of General Psychology, University of Padova

The natural environment is rich with colors. Objects contain a multitude of hues that depend on texture and shape, the positions of other objects and light sources. Yet, little is known about how human observers represent such color distributions. Previous research shows that observers can estimate means and variance of feature distributions, but whether shapes of distributions can be represented is less well known. We introduce a new method for studying representations of color ensembles based on intertrial learning in visual search. Observers looked for the oddly colored diamond among multicolored diamonds taken from either uniform or Gaussian color distributions. Color space was corrected for inequalities in average sensitivity to different colors, so that adjacent hues were separated by 1 average JND (Witzel and Gegenfurtner, 2013, 2015). Within "streaks" of 3-4 trials, distractor colors were randomly drawn from either a Gaussian or uniform distribution. On test trials the targets had various distances in color space

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from the mean of the preceding distractor color distribution allowing us to estimate the shape of representations of distractor sets. Targets therefore served as probes into representations of distractor colors. We analyzed response times on test trials as a function of differences between target color and the preceding distribution. Our results show that after only 3-4 exposures to a particular color distribution, observers obtained a detailed representation of that distribution revealing a striking similarity between the physical distribution of colors and their internal representations. The results demonstrate that the visual system represents color ensembles in a more detailed way than previously thought, coding not only mean and variance but most surprisingly, the actual shape of the distribution of colors in the environment.

Acknowledgement: Funded by the Icelandi Research Fund (IRF)

53.4104 Texture density aftereffect is bidirectional Hua-Chun Sun[1](hua-chun.sun@mail.mcgill.ca), Frederick Kingdom[2], Curtis Baker[3]; [1]McGill Vision Research, Department of Ophthalmology, McGill University

It has been suggested that adaptation to texture density only ever reduces, i.e. never increases, perceived density, implying that density adaptation is 'uni-directional' and that texture density is coded as a scalar attribute (Durgin & Huk, 1997). However we have recently shown that simultaneous density contrast, which describes the effect of a surround texture on the perceived density of a centre region, is 'bi-directional' - that is, not only do denser surrounds reduce perceived density of the center but sparser surrounds enhance it (Sun, Baker, & Kingdom, 2016). Therefore we decided to re-examine the directionality of density adaptation. To do this we measured the density aftereffect in random dot patterns using a 2AFC matching procedure that established a PSE (point-of-subjective-equality) between an adapted test patch and an unadapted match patch. The adaptors and test were presented at the same position, either at top left or bottom right of the fixation. The match was presented at bottom left or top right correspondingly. These positions were fixed within a block and switched between blocks. In the first experiment we established that bi-directionality could indeed be obtained, provided the test and match were presented sequentially not simultaneously. Then, using sequential presentation, we measured the density aftereffect for a wide range of adaptor and test densities. We found bi-directionality for all combinations of adaptor and test densities, with the exception of one of the test conditions in one of the four observers. In line with our previous results with simultaneous density contrast, this evidence supports the idea that there are multiple channels selective to texture density in human vision.

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53.4105 Towards a model for sensitivity to local image statistics Jonathan Victor[1](jdvicto@med.cornell.edu), Syed Rizvi[1], Jacob Bush[1], Mary Conte[1]; [1]Feil Family Brain and Mind Institute, Weill Cornell Medical College

Many early visual processes, including segmenting an image into its components and analyzing their surface properties, depend on local image statistics. Modeling the underlying visual computations is challenging, owing to the high dimensionality of image statistics and the potential for complex interactions. We therefore took an indirect approach, beginning with black-and-white textures with local spatial correlations. In this stimulus space, image statistics can be independently probed and fully analyzed, leading to a predictively accurate model of psychophysical sensitivities. Here, we show that key aspects of these findings extend to images with three luminance levels, and are also consistent with Chubb et al.'s (2007) studies of "scramble" textures with multiple gray levels. To investigate ternary textures, we developed a stimulus domain parameterized by the probabilities of all configurations of black, gray, and white checks in 2x2 neighborhoods (with gray halfway between black and white). This space has 66 free parameters. Each parameter corresponds to an image statistic: 2 first-order, 16 second-order, 32 third-order, and 16 fourth-order. Taking symmetry into account, the 66 statistics fall into 12 distinct categories. Sensitivity to these statistics was quantified in N=5 subjects, using a 4-AFC segmentation task. Stimuli consisted of 64x64 arrays of 14-min checks, containing a 16x64 target in one of four possible locations. We found that all first- and second-order statistics were salient, as were selected third- and fourth-order statistics. Consistent with findings for binary textures, results showed (i) nearly equal sensitivities to increments and decrements of an image statistic, and (ii) elliptical isodiscrimination contours indicating quadratic combination of signals. We also note that the Chubb model for discrimination of "scramble" textures with multiple gray levels has a probabilistic formulation that applies to textures with spatial correlation, and this formulation is at least qualitatively consistent with our key findings.

Acknowledgement: NIH EY07977

Scene Perception

Tuesday, May 23, 2:30 - 4:15 pm
Talk Session, Talk Room 1
Moderator: Aude Oliva

54.11, *2:30 pm* **Convolutional neural networks best predict representational dissimilarity in scene-selective cortex: comparing computational, object and functional models** Iris Groen[1](iris.groen@nih.gov), Michelle Greene[2], Christopher Baldassano[3], Li Fei-Fei[2], Diane Beck[4], Christopher Baker[1]; [1]Laboratory of Brain and Cognition, National Institutes of Mental Health, [2]Department of Computer Science, Stanford University, [3]Princeton Neuroscience Institute, Princeton University, [4]Department of Psychology and Beckman Institute, University of Illinois at Urbana-Champaign

Complex scene perception is characterized by the activation of scene-selective regions PPA, OPA and MPA/RSC. So far, these regions have been mostly interpreted as representing visual characteristics of scenes, such as its constituent objects ("an oven"), spatial layout ("a closed space"), or surface textures ("wood and granite"). Recent behavioral evidence, however, suggests that the functions afforded by a scene ("Could I prepare food here?") play a central role in how scenes are understood (Greene et al., 2016). Here, we used a model-based approach to study how the brain represents scene functions. Healthy volunteers (n=20) viewed exemplars from 30 scene categories in an ultra-high-field 7T MRI scanner. Stimuli were carefully selected from a larger set of scenes characterized in terms of their visual properties (derived computationally using a convolutional neural network, CNN), object occurrence, and scene function (derived using separate behavioral experiments), such that each model predicted a maximally different pattern of brain responses. Variation partitioning on multi-voxel response patterns showed that the CNN model best predicted responses in scene-selective regions, with limited additional contribution from the other models. Representations in scene-selective regions correlated best with higher CNN layers; however, responses in PPA and OPA, but not MPA/RSC, also correlated with lower layers. A whole-brain analysis showed that the CNN model contribution was restricted to scene-selective cortex, while the functional model selectively predicted responses in a posterior left-lateralized region associated with action representation. These results show that (high-level) visual properties predict scene-selective regions better than functional properties. However, understanding scene functions may engage other regions than those identified based on scene-selectivity. Further research is needed to determine whether scene functions are better captured by regions outside the scene network or perhaps are better thought of as semantic affordances mediated by visual representations in the higher layers of the CNN.

Acknowledgement: Intramural Program of NIMH Netherlands Organization of Scientific Research

54.12, *2:45 pm* **The neural separation and integration of object and background scene information in natural images** Caitlin Mullin[1](crmullin@mit.edu), Seyed-Mahdi Khaligh-Razav[1], Dimitrios Pantazis[2], Aude Oliva[1]; [1]Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology, Cambridge, MA, [2]McGovern Institute for Brain Research, Massachusetts Institute of Technology, Cambridge, MA, USA

A major challenge of scene understanding is to describe how information from multiple brain regions, is synthesized over time. Behavioral and neurological evidence suggests a division of object and scene background processing into distinct neural pathways. Despite extensive investigation, whether these pathways function sequentially or in parallel remains unknown. Here, we investigated the spatial and temporal representation of scene perception, from the deconvolution of a singular natural image into separate object and background information to their recombination into a unified percept. During individual MEG and fMRI sessions, participants viewed a series of natural images containing objects orthogonally paired with different backgrounds. Outside the scanner, participants arranged these stimuli based on the similarity of their object and background content separately. We then employed representational similarity analysis to correlate the behavioral representations of the object and scene background with activity-pattern representational dissimilarity matrices of the brain over space (fMRI) and time (MEG). Results from MEG analysis support the parallel processing pathways of object and background information with both signal onsets occurring simultaneously at ~100ms. However, these signals deviate after onset with scene backgrounds showing a transient response while objects were more sustained over time. fMRI searchlight analysis revealed distinct as well as overlapping regions corresponding to the representational similarity of both object and background. While expected regions such as lateral occipital and retrosplenial cortex were correlated with object and background representations respectively, the transverse occipital sulcus and parahippocampal cortex correlated with both representations. This suggests that while some regions parse the visual input into background and object others may treat the image in its entirety. These findings shed light on how the higher-order properties of images are separated and converge in specific brain regions at different stages of processing to enable our unified visual experience.

Acknowledgement: Martinos Imaging Center at MIT

54.13, *3:00 pm* **Active Exploration Benefits Memory for 360º Scenes Experienced with Headmounted Virtual Reality** Anna Mynick[1](amynick@wellesley.edu), Caroline Robertson[2,3], Nancy Kanwisher[3]; [1]Neuroscience Department, Wellesley College, Wellesley, MA, [2]Harvard Society of Fellows, Harvard, Cambridge, MA, [3]McGovern Institute for Brain Research, MIT, Cambridge, MA

Intro: Typical development of basic visual functions depends on active self-motion through a visual environment (as opposed to passive viewing), yet whether self-motion impacts visual scene perception in adults is unknown. To find out, we tested memory for real-world panoramic scenes studied in head-mounted virtual reality with either with active self-motion or passive viewing. Methods: 24 participants viewed 36 novel, real-world 360º photospheres through a headmounted Virtual Reality Display (Oculus Rift). Scenes were presented through the Oculus Rift in three conditions, in which participants: (1) actively explored through the use of head turns (Oculus Condition), (2) actively explored using a joystick to change viewpoints while head position remained fixed (Joystick Condition), or (3) passively viewed "Playback" recordings of active exploration trials by different individuals (Video Condition). Subsequently, three memory tests were administered. Memory Test 1, Recognition Memory: Participants were asked to recall whether they had viewed a snapshot showing a 90º subset of a studied photosphere. Memory Test 2, Panoramic Memory: Participants judged the relative spatial positioning of two scene snapshots. Memory Test 3, Spatial Memory: Participants judged whether a scene snapshot had appeared on the left or right side of the scene. Results: We observed a main effect of study condition on memory performance ($F(2,44)=13.6$, $p=0.01$): overall, self-directed, first-person experience increased subsequent scene memory over passive viewing (Oculus > Joystick > Video Condition). We also observed an interaction between study condition and memory test ($F(4,88)=9.5$, $p=0.01$): Performance on Memory Test 2 was particularly enhanced by fully active viewing (Oculus > Joystick, $p=0.038$). Conclusions: Our results demonstrate that active engagement with a panoramic environment parametrically benefits subsequent scene memory. The strength of this benefit for panoramic memory in particular suggests that panoramic memory formation may be facilitated by a mapping between viewpoints and head-orientation.

54.14, *3:15 pm* **The perceptual advantage of symmetry for scene perception** John Wilder[1](jdwilder@cs.toronto.edu), Morteza Rezanejad[2], Sven Dickinson[1], Kaleem Siddiqi[2], Allan Jepson[1], Dirk Walther[3]; [1]Department of Computer Science, University of Toronto, [2]Centre for Intelligent Machines and School of Computer Science, McGill University, [3]Department of Psychology, University of Toronto

As one of the original Gestalt principles, symmetry is believed to support visual perception by aiding the visual system in detecting objects, which tend to be symmetric. Whereas the role of symmetry for the perception of isolated objects has been well studied, it is so far unknown what role symmetry plays in the perception of cluttered, real-world scenes. We demonstrate, for the first time, a strong perceptual advantage of local contour symmetry for perceiving complex real-world scenes. Unlike global symmetry, local symmetry is largely invariant to pose. Scenes were represented as line drawings, which have been shown to capture essential structural information required for successful scene categorization (Walther et al., 2011). We assessed local symmetry by computing the degree to which contour pixels participate in non-accidental symmetry relationships in the scene, using the medial axis transform (Blum, 1973; Siddiqi et al, 2008). Each contour pixel was assigned a numerical symmetry value based on the rate of change of the radius function of the medial branch to which it was assigned. We then generated two alternate versions of each line drawing, one with the half of the pixels ranked most symmetric and one with the half ranked least symmetric. The two types of modified line drawings were shown to twelve participants along with intact line drawings in a six-alternative forced-choice scene categorization experiment with short presentations (53 ms), followed by a perceptual mask. Each participant saw 20 images from each category, per condition (360 total trials). Participants' categorization accuracy was significantly higher for the most symmetric contours (49.7%) than for the least symmetric contours (38.2%), with intact contours showing higher performance than both modified conditions (65.8%). These results demonstrate, for the first time, the role of local contour symmetry as a crucial organizing principle in complex real-world scenes.

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54.15, *3:30 pm* **Object segmentation controls image reconstruction from natural scenes** Peter Neri[1](neri.peter@gmail.com); [1]Laboratoire des Systèmes Perceptifs, École Normale Supérieure, Paris (France)

Retinal projections often poorly represent the structure of the physical world: well-defined boundaries within the eye may correspond to irrelevant features of the physical world, while critical features of the physical world may be nearly invisible at the retinal projection. The challenge for visual cortex is to sort these two types of features according to their utility in interpreting the scene. We describe a novel paradigm that enables selective evaluation of the relative role played by these two feature classes in signal reconstruction from corrupted natural images. Our behavioural and EEG measurements demonstrate that this process is quickly dominated by the inferred structure of the environment, and only minimally controlled by variations of raw image content. The inferential mechanism is spatially global and its impact on early visual cortex is fast. Furthermore, it retunes local visual processing for more efficient feature extraction without altering the intrinsic transduction noise. The basic properties of this process can be partially captured by a combination of small-scale circuit models and large-scale network architectures. Our results challenge compartmentalized notions of bottom-up/top-down perception, and suggest instead that these two modes are best viewed as an integrated perceptual mechanism.

Acknowledgement: CNRS (France), Royal Society (UK)

54.16, *3:45 pm* **Object, scenes, and the spaces in between: Workspaces have distinctive perceptual and semantic content** Emilie Josephs[1](ejosephs@g.harvard.edu), Talia Konkle[1]; [1]Psychology, Graduate School of Arts and Sciences, Harvard

Imagine composing an email or chopping carrots. These tasks, and many more, are performed in spaces of similar scale and structure—in "workspaces." We define workspaces as environments slightly deeper than arm's reach, containing task-relevant objects on a horizontal surface. Here, we examined whether views of workspaces have distinctive perceptual and semantic signatures compared to views of singleton objects and canonical scenes. First, using visual search as an index of perceptual similarity, we asked whether workspaces have distinctive perceptual features from scenes and objects. If workspaces differ perceptually, they should be found faster among scenes or objects than among other workspaces. Indeed, response times showed evidence for a 3-way dissociation among objects, workspaces, and scenes (Exp 1: stimuli luminance-matched; Exp 2: luminance- and spatial frequency-matched), providing initial evidence that workspace views have distinctive perceptual features from views of full scenes or single objects. Second, using semantic priming, we examined whether workspaces have stronger associations to action concepts than full scenes. Participants indicated whether a target word was an action or emotion verb, while ignoring a task-irrelevant image of either a scene or a workspace. Critically, the action word was either semantically congruent to the image (e.g. "chopping" for a kitchen workspace or scene), or incongruent (e.g. "ironing"). Congruent action words were categorized faster than incongruent ones, but only in the presence of workspace views, not in the presence of scene views (interaction term: $p < 0.05$). These data show that workspace views automatically trigger action-related processing in a way that differs from scenes. Together, these results suggest that workspace views have distinctive perceptual features and privileged relationships to action-related concepts, providing initial evidence that workspace views constitute a division of visual space that is distinct from both objects and scenes in how it interfaces with our visual cognitive systems.

54.17, *4:00 pm* **Encoding of event roles from visual scenes is rapid, automatic, and interacts with higher-level visual processing** Alon Hafri[1](ahafri@sas.upenn.edu), John Trueswell[1], Brent Strickland[2]; [1]Department of Psychology, University of Pennsylvania, [2]Département d'Etudes Cognitives, Ecole Normale Supérieure, PSL Research University Institut Jean Nicod (ENS, EHESS, CNRS)

To successfully communicate about and navigate a perceptually chaotic world, we must not only extract the identities of people, but also the roles that they play in events, i.e. who did what to whom: Boy-hitting-girl is very different from girl-hitting-boy. We routinely categorize Agents (i.e. the actor) and Patients (i.e. the one acted upon) from visual input, but even when attention is otherwise occupied, do we automatically encode such roles? To investigate this question, we employed a "switching cost" paradigm. In several experiments, participants observed a continuous sequence of two-person event scenes and had to rapidly identify the side of a target actor in each (the male/female, or the red/blue-shirted actor). Critically, although role was orthogonal to gender and shirt color, and was never explicitly mentioned, participants responded more slowly when the target's role switched from trial to trial (e.g., the male went from being Patient to Agent). Despite the small absolute magnitude of this role switch cost, it was both significant and robust (all p's < 0.001, Cohen's d's > 0.86), with a majority of subjects and items demonstrating the effect. In an additional experiment, we probed the level of representation at which the role switch cost operates. We ran the same paradigm as before but edited the images such that actors always faced opposite directions ("mirror-flipped"). Thus, actor poses were preserved but their interaction was eliminated. The switch cost here was significantly lower, and additional "active posture" saliency effects emerged. This indicates that the role switch cost in our previous experiments cannot be fully explained by mere pose differences associated with Agents and Patients. Taken together, our experiments demonstrate that the human visual system is automatically engaged in extracting the structure of an event, i.e. who did what to whom, even when attention is directed toward other visual features.

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ATTENTION: NEURAL MANIPULATION AND MECHANISM

Tuesday, May 23, 2:30 - 4:15 pm
Talk Session, Talk Room 2
Moderator: Tony Ro

54.21, *2:30 pm* **tRNS facilitates perceptual learning on cross-task training** Federica Contò[1,2](federica.conto@unitn.it), Lorella Battelli[2,3]; [1]Center for Neuroscience and Cognitive Systems@UniTn, Istituto Italiano di Tecnologia, Via Bettini 31, Rovereto, 38068, Italy, [2]Center for Mind/Brain Sciences, University of Trento, Via Bettini 31, Rovereto, 38068, Italy, [3]Berenson-Allen Center for Noninvasive Brain Stimulation and Department of Neurology, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, Massachu

Tuesday PM

Introduction. tRNS has been used to modulate cortical excitability and facilitate behavior, particularly using perceptual learning tasks. Typically, these studies analyze the facilitatory effects on a single task, and its transfer to untrained tasks. Yet, there is a lack of studies that investigate the impact of tRNS during cross-task training. In these experiments we explored the effect of dual-task training using identical visual stimuli across two different attentional tasks. We used tRNS to modulate learning to identify the cortical site directly involved in cross-task training. Methods. Subjects participated in a 6-days experiment (1 session/day). During each session, subjects were simultaneously trained on two tasks: a temporal order judgment (TOJ) and an orientation discrimination (OD), using two Gabors presented to the left and right of fixation. Each subject was trained at their individual TOJ and OD psychophysical thresholds, across two levels: easy and hard trials. At the beginning of each trial, subjects were instructed which of the two tasks to perform. These two tasks were randomly intermixed within each block. Subjects were assigned to one of three conditions in a between-subject design: tRNS over hMT+, tRNS over parietal cortex and sham stimulation. Active tRNS or sham were delivered for 25 minutes concurrent with the task, during days 2-4 (training phase). We expected tRNS over parietal to selectively impact and enhance training. Results. Participants' performance significantly improved in both tasks (TOJ and OD) after tRNS over parietal compared to hMT+ and sham. Crucially this improvement was selective for difficult trials only for both tasks. Conclusions. These findings demonstrate the direct involvement of the parietal cortex in perceptual learning, while subjects are simultaneously training on two cognitive tasks that are visually identical but require different attentional processes (temporal and spatial).

54.22, *2:45 pm* **Cross-modal attention effects in vestibular cortex during attentive tracking of moving objects** Mark Greenlee[1](mark.greenlee@psychologie.uni-regensburg.de), Sebastian Frank[2], Liwei Sun[2], Lisa Forster[1], Peter Tse[2]; [1]Institute of Experimental Psychology, University of Regensburg, 93053 Regensburg, Germany, [2]Department of Psychological and Brain Sciences, Dartmouth College, Hanover, NH 03755, USA

It is now well established that activity in sensory systems is subject to cross-modal attention. Attending to a stimulus in one sensory modality enhances activity in that sensory system, but simultaneously suppresses activity in other sensory systems. Here, we determined whether such cross-modal attention affects activity in the vestibular system. To this end, we employed a visual multiple object tracking task. We varied the number of tracked targets to measure the effect of attentional load on vestibular (parieto-insular vestibular cortex: PIVC) and visual-vestibular (posterior insular cortex: PIC) areas, while holding perceptual load constant. Participants performed the tracking task during functional magnetic resonance imaging (fMRI). Compared to passive viewing of multiple-object motion, activity during object tracking was increased in visual area MT+, posterior parietal cortex (PPC) and the frontal eye fields (FEF) in a load-dependent manner (replicating eariler results, Culham et al., 2001, Neuron, 32, 737–745). At the same time, activity in PIVC was suppressed and this suppression of activity increased with increasing attentional load. A similar load-dependent effect was evident in the anterior part of PIC, such that activity decreased with greater loads, whereas it was absent in posterior PIC. These results suggest that attention has a cross-modal modulatory effect on vestibular cortex during visual object tracking. Further results of a control experiment show that most of the suppression in PIVC is not caused by the visual stimulus per se, but by attention to the visual stimulus, suggesting that inhibitory interactions between sensory systems might not be hard-wired, but flexible, and depend on the allocation of attention to a particular sensory domain.

Acknowledgement: Deutsche Forschungsgemeinschaft, Humboldt Foundation

54.23, *3:00 pm* **Visual, spatial, or visuospatial? Disentangling sensory modality and task demands in frontal cortex.** Abigail Noyce[1](anoyce@bu.edu), Sean Tobyne[1], Samantha Michalka[2], David Osher[1], Barbara Shinn-Cunningham[1], David Somers[1]; [1]Boston University, [2]Olin College

Vision has an intrinsic affinity for spatial information, such that visual processing and spatial representations are often confounded in neuroimaging research. Recently, our laboratory used fMRI to demonstrate that directly contrasting visual and auditory attention or working memory robustly identifies discrete visual- and auditory-biased structures in caudolateral frontal cortex. Further, these areas are recruited cross-modally depending on task demands, with auditory spatial tasks recruiting visual-biased areas, and visual temporal tasks recruiting auditory-biased areas (Michalka 2015). Resting state functional connectivity between frontal cortex and posterior visual (IPS/TOS) and auditory (STG/S) structures identified additional frontal regions with preferential connectivity to one or the other posterior seed. In individual subjects, we identified four bilateral sensory-biased structures in the vicinity of the precentral sulcus and inferior frontal sulcus using a direct contrast of visual and auditory attention. We additionally defined four adjacent sensory-biased structures using individual subjects' resting state functional connectivity; these areas ("buddy regions") have similar degrees of preferential connectivity to the task-defined posterior structures, but are not selectively recruited in contrasts of visual vs. auditory cognition. Using auditory and visual working memory tasks in which subjects either remembered locations (spatial memory) or time intervals (temporal memory), we tested the degree of recruitment in task-defined visual- and auditory-biased frontal structures, as well as in the buddy regions. Preliminary results suggest that the buddy regions are strongly cross-modally recruited during modality-inappropriate tasks. In auditory spatial memory, the task-defined superior precentral sulcus, a visual-biased structure, is recruited, but the adjacent connectivity-defined region is driven substantially more strongly. These buddy regions, with sensory-biased connectivity but minimal sensory-biased task recruitment, may play important roles in flexible human cognition, allowing the brain to translate between representations depending on task demands (Marr 1982).

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54.24, *3:15 pm* **Predicting trial-by-trial attention dynamics during human reinforcement learning** Angela Radulescu[1](angelar@princeton.edu), Yuan Chang Leong[2], Yael Niv[1]; [1]Department of Psychology and Princeton Neuroscience Institute, [2]Department of Psychology, Stanford University

Selective attention is thought to facilitate reinforcement learning (RL) in multidimensional environments by constraining learning to dimensions that are most relevant for the task at hand. But how would agents know what dimensions to attend to in the first place? Here we use computational modeling of human attention data to show that selective attention is sensitive to trial-by-trial dynamics of reinforcement. Twenty-five participants performed a decision-making task with multi-dimensional stimuli, while undergoing functional magnetic resonance imaging (fMRI) and eye-tracking. At any one time, only one of three stimulus dimensions (faces, houses or tools) was relevant to predicting probabilistic reward. Participants had to learn, through trial and error, which was the predictive dimension, and what feature within that dimension was the most rewarding. We chose this task design in order to capture real-world learning problems where only some dimensions in the environment consistently predict noisy reward. In previous work we showed that attention to different dimensions modulates learning in this task. To examine how subjects learn what to attend to, we developed and compared different models that specify how attention changes trial-by-trial. Both the neural and eye-tracking data were best explained by an RL model that tracks feature values learned from trial-and-error, and allocates dimensional attention in proportion to the highest valued feature along each dimension. This model outperformed models that determined attention based on choice history alone, suggesting that attention dynamically changes as a function of recent reward history. To our knowledge, ours is the first explanation of how attention measured directly and simultaneously from neural data and eye-tracking is determined. Our results establish a bidirectional interaction between attention and RL: attention constrains what we learn about, and learned values determine what we attend to.

54.25, *3:30 pm* **At what latency does the phase of brain oscillations influence perception?** Sasskia Brüers[1,2](bruers@cnrs.fr), Rufin VanRullen[1,2]; [1]Univerisité de Toulouse 3 Paul Sabatier, Toulouse France, [2]Centre de Recherche Cerveau et Cognition, CNRS, UMR 5549

Our perception of the world appears deceptively continuous. In reality, our brains take "snapshots" of the surrounding environment from 5 to 15 times a second, creating "perceptual cycles". At the neuronal level, this is evidenced by fluctuations in the excitability of the cortex as a function of the local field potential phase: spikes are more likely to occur at a given phase of the cycle. These fluctuations have also been documented in human observers: for example, subjects are more likely to detect a threshold-level target at a given EEG phase, and less likely at the opposite phase. Yet, most studies usually report EEG phase modulations peaking 100-200ms before stimulus onset. Presumably, the phase that matters for perception should be the one present in the brain during information processing. Why is the phase modulation usually not detectable after stimulus onset? First, we use simulations to show that the target-evoked ERP (together with signal filtering) results in an apparent shift of the peak phase modulation back in time, even before stimulus presentation. Second, we present a novel method, the "white-noise paradigm", which can be used to uncover the true latency of phase modulation effects, free of any contamination by the ERP. The impulse response functions of twenty subjects recorded during a first session were used to reconstruct (rather than record) the brain activity to (new) white-noise sequences presented in a second session. The background oscillatory phase around targets embedded within these sequences could then be reliably estimated, without any influence of the target-evoked response. Using these reconstructed signals, we found that the fronto-occipital ~6Hz oscillatory phase at about 70 ms after target onset is the one that matters for perception. These results confirm the causal influence of phase on perception, at the time the stimulus is actually processed by the brain.

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54.26, *3:45 pm* **Alpha Oscillations Reflect Feedback Processing for Visual Awareness** Tony Ro[1](tro@gc.cuny.edu), Jeremy Fesi[1]; [1]The Graduate Center, CUNY

Sometimes one person can miss a brief visual event that others may readily detect. This variability in visual awareness may be a consequence of different processing times in visual cortex for different individuals. We and others have previously shown that specific temporal processing windows, namely later feedback activity to primary visual cortex (V1) (Supèr et al., 2001; Ro et al., 2003) and the phase of alpha (8-12 Hz) oscillations (Mathewson et al., 2009; Jaegle & Ro, 2014), are important for visual awareness. Recent evidence also suggests that alpha oscillations arise from feedback activity to V1 (van Kerkoerle et al., 2014). In the current study, we assessed whether alpha oscillations reflect feedback/reentrant activity by testing the relationship between peak alpha oscillation frequency and signatures of feedback processing in V1 for conscious visual perception. Using scalp electroencephalography (EEG) recordings, single-pulse transcranial magnetic stimulation (TMS), and metacontrast masking, we show that individual peak alpha oscillation frequencies are highly correlated with optimal TMS visual suppression times and metacontrast masking latencies, both of which have been suggested to index feedback processing in V1. These findings suggest that alpha oscillations reflect waves of feedback activity to V1 for visual awareness and that the time to visual awareness varies across individuals.

Acknowledgement: NSF BCS 1561518

54.27, *4:00 pm* **Learning Mechanisms Underlying Value-Driven Attention** Brian Anderson[1](brian.anderson@tamu.edu), Hiroto Kuwabara[2], Dean Wong[2,3,4], Joshua Roberts[2], Arman Rahmim[2], James Brašić[2], Susan Courtney[3,5,6]; [1]Department of Psychology, Texas A&M University, [2]Russell H. Morgan Department of Radiology and Radiological Science, Johns Hopkins University School of Medicine, [3]Solomon H. Snyder Department of Neuroscience, Johns Hopkins University School of Medicine, [4]Department of Psychiatry and Behavioral Sciences, Johns Hopkins University School of Medicine, [5]Department of Psychological and Brain Sciences, Johns Hopkins University, [6]F. M. Kirby Research Center, Kennedy Krieger Institute

Reward learning can shape attentional priorities such that previously reward-associated stimuli capture attention. The neural correlates of value-driven attention have become a topic of increasing interest, with studies revealing multiple brain areas throughout the visual system that show elevated responding to previously reward-associated distractors. These prior studies, however, have tended to focus on the consequences of reward learning, without addressing the learning mechanisms responsible. We will present two studies that begin to tackle this difficult and important issue. Using whole-brain fMRI, we measured reward processing in the training phase of the value-driven attentional capture paradigm (Anderson et al., 2011). The receipt of high reward evoked elevated activity in regions commonly attributed to reward processing, but also in several visual areas previously implicated in value-driven attention. These reward signals in visual areas contained information about the immediately preceding target stimulus, such that its position and identity could be reliably decoded from the reward-evoked activity on high- but not low-reward trials. In a second study using PET, we measured dopamine release during visual search with and without reward feedback. Attentional capture by previously reward-associated stimuli in a subsequent test phase was strongly correlated with changes in endogenous dopamine levels within the striatum attributable to the processing of reward during training. Together, these studies suggest a possible learning mechanism underlying value-driven attention. Dopaminergic reward signals from the striatum predict subsequent capture, and could serve as the putative teaching signals to visual areas measured using fMRI. With repeated stimulus-reward pairings, these teaching signals could serve to potentiate the rewarded visual representation, allowing the associated object to compete more effectively for selection. The proposed learning mechanism can account for classical value-driven attentional capture, attentional capture by reward cues that are never targets, and reward-mediated priming, offering a unifying account of reward-related attention effects.

Acknowledgement: R01-DA013165, S10-RR017219, S10-RR023623

Development

Tuesday, May 23, 5:15 - 7:15 pm
Talk Session, Talk Room 1
Moderator: Jan Atkinson

55.11, *5:15 pm* **Reduced Frequency of Motion Induced Blindness in Autism** Caroline Robertson[1,2](carolinerobertson@fas.harvard.edu), Jackson Lee[3], Nancy Kanwisher[2]; [1]Harvard Society of Fellows, Harvard, Cambridge, MA, [2]McGovern Institute for Brain Research, MIT, Cambridge, MA, [3]Duke Institute for Brain Sciences, Duke, Durham, NC

Intro: Bistable perception is known to rely in part on the balance of inhibitory/excitatory neurotransmission in the brain, and therefore may provide a behavioral index of alterations in inhibition that are thought to characterize autism. Indeed, we recently demonstrated a striking reduction in perceptual suppression during binocular rivalry in autism, which linked to reduced GABAergic action in the autistic brain (Robertson et al., 2013, 2016). Here, we test whether this behavioral difference generalizes to another class of bistable stimuli, motion-induced blindness, which is known to tax competitive interactions in different regions of the brain than rivalry (Donner et al., 2008, 2013). Methods: 38 adults (18 ASD, matched for age and IQ) participated in a simple motion-induced blindness study (Bonneh et al., 2001). On each of the 24 16-second long trials (2 practice and 22 experimental), participants reported the duration and frequency of target disappearances using a button press. Half of the trials included "catch trials" in which a target was physically removed from the display at a random timepoint during the trial (duration: 1.75s). Results: The frequency of target disappearances was significantly lower for participants with ASC than for controls ($t(37)=2.70$, $p=0.01$), while the average duration of each target disappearance was equivalent across groups ($t(36)=0.43$, $p=0.63$). The frequency of MIB inversely predicted autism symptom severity (ADOS scores): individuals with reduced perceptual suppression exhibited higher autistic symptomatology ($rho=-0.51$, $p=0.03$). Critically, the two groups were matched on their accuracy and RTs to detect catch trials (both $p>0.53$). Conclusions: Individuals with autism demonstrate a reduced frequency of motion-induced blindness. These results cannot be explained by group differences in motor latencies, and are predictive of autistic symptom severity. Together with our previous findings in binocular rivalry, these results suggest that reduced perceptual suppression may be a generalizable characteristic of autistic vision.

55.12, *5:30 pm* **Direction and orientation integration in autistic children** Catherine Manning[1](catherine.manning@psy.ox.ac.uk), Marc Tibber[2], Steven Dakin[3,4]; [1]Department of Experimental Psychology, University of Oxford, [2]Camden and Islington NHS Foundation Trust, [3]Department of Optometry and Vision Science, University of Auckland, [4]UCL Institute of Ophthalmology, University College London

Tuesday PM

 See page 3 for Abstract Numbering System

Introduction: Vision in autistic people has been characterised as detail-focused, with a disinclination (or reduced ability) to integrate information into coherent "wholes". Yet, we recently demonstrated enhanced motion integration in autistic children (Manning et al., 2015, J Neurosci, 35(18), 6979-6986). Here, we investigated the robustness of our finding of increased motion integration in autism with a new sample of children, and determined whether increased integration would extend to a static, orientation judgement. Methods: We presented motion and orientation equivalent noise and coherence tasks to 46 autistic children aged 6 to 14 years and 45 typically developing children matched in age and non-verbal IQ. The equivalent noise tasks consisted of two interleaved conditions: a high-noise condition in which children judged the average direction or orientation of elements whose range of direction or orientations was manipulated, and a no-noise condition in which children judged the direction or orientation of identical elements. In the coherence tasks, the proportion of signal elements sharing the same direction or orientation amidst otherwise random noise elements was manipulated. Results: When combining motion data from this and the original experiment, autistic children exhibited superior integration of direction information in the high-noise condition compared to typically developing children (indexed by higher maximum tolerable noise values), yet had similar no-noise and coherence thresholds. Equivalent noise modelling of these data revealed increased sampling in autistic children for motion information but no conclusive evidence for atypical levels of internal noise. There was no evidence of differences between autistic and typically developing children in the orientation equivalent noise and coherence tasks. Conclusion: Overall, autistic children effectively integrate more direction information than typically developing children, notwithstanding considerable individual variability. There was no indication of atypical integration of orientation. These results call into question accounts of reduced integration in autistic perception.

Acknowledgement: The research was funded by a Scott Family Junior Research Fellowship at University College and an Oxford University Press (OUP) John Fell Fund grant awarded to CM.

55.13, *5:45 pm* Reading intervention induces change in white matter and behavior Elizabeth Huber[1](ehuber@uw.edu), Patrick Donnelly[1,2], Ariel Rokem[3], Jason Yeatman[1,2]; [1]Institute for Learning and Brain Sciences, University of Washington, [2]Department of Speech and Hearing Sciences, University of Washington, [3]eScience Institute, University of Washington

Skilled reading requires orchestration of a large cortical network, and individual differences in reading performance have previously been linked to properties of relevant anatomical connections. However, it is not known how experience shapes this network, or whether correlations between anatomy and behavior are stable. To investigate the relationship between reading experience, reading skills, and white matter properties, we carried out a longitudinal study in children with reading difficulties (n=23, ages 6-12) who participated in an 8-week, intensive reading intervention. Along with behavioral measures, we collected diffusion MRI data over 4 sessions, separated by 2-week intervals. We first examined a set of white matter tracts considered to be part of the core circuitry for reading: the occipital callosal connections, left arcuate fasciculus (AF), and left inferior longitudinal fasciculus (ILF). Over the intervention, we observed changes in diffusion properties within the latter two tracts. Specifically, mean diffusivity (MD) decreased in the AF and ILF as a function of reading experience. In contrast, diffusion properties were stable in the occipital callosal connections. We next examined the relationship between MD values and reading skills. Only the callosal fibers clearly predicted reading skills in the intervention subjects. We therefore suggest that differences in MD within occipital callosal connections reflect relatively stable anatomical variation, which predicts reading skill but does not change during short-term, intensive training. Finally, to examine the anatomical specificity of intervention-driven changes, we performed hierarchical clustering based on the correlations between linear growth rates in 16 anatomical tracts. This analysis identified a cluster comprising the main cortical association tracts (left arcuate, left and right ILF, SLF, IFOF, and uncinate), which have previously been implicated in reading-related tasks. Large-scale change within this network may be a hallmark of rapid, short-term plasticity associated with intensive training of reading skills.

Acknowledgement: NSF/SBE-BSF 1551330

55.14, *6:00 pm* How does poor initial acuity impact visual development? A computational investigation Lukas Vogelsang[1](lvogelsa@mit.edu), Evan Ehrenberg[1], Sharon Gilad-Gutnick[1], Pawan Sinha[1]; [1]Department of Brain and Cognitive Sciences, MIT

Previous studies suggest that individuals who were treated for congenital cataracts early in life are impaired at configural face processing, displaying difficulties detecting subtle differences in the spatial arrangement of facial features. While most accounts of such deficits have focused on the role of a critical period, we recently proposed a theory suggesting such deficits may result from the abnormally high initial acuity that these individuals experience upon sight onset. According to this theory, the initial low acuity period of the normally developing visual system may play a key role in developing the expertise in configural processing that is required for face individuation later in life, by forcing the visual system to integrate information over large image-patches in order to resolve diagnostic information from low-resolution input. To test the computational soundness of this theory, we trained two instances of a convolutional neural network (CNN) in order to model how early neural layers of a theoretical visual system may develop when trained on low vs. high-resolution face images. We found that the CNN instance trained on low-resolution face images developed larger wavelet patches in the first convolutional layer, leading to better generalization performance on test images, regardless of their resolution. Our findings support the perhaps counter-intuitive idea that training a visual system on optimal (high-resolution) input may actually be detrimental to the development of face individuation, as it may not force the visual system to integrate information over larger receptive fields, a process that is particularly crucial for configural processing.

Acknowledgement: Grant R01EY020517 from National Eye Institute (NIH)

55.15, *6:15 pm* How Visual Experience Shapes Object Recognition in the Newborn Brain: A Controlled Rearing Approach Justin Wood[1](justin.wood@usc.edu); [1]Department of Psychology, University of Southern California

How does the brain learn to recognize objects? Although researchers have debated the origins of object recognition for decades, it had not been possible to examine how high-level visual abilities emerge in the newborn brain with high precision. To overcome this barrier, my lab developed an automated controlled-rearing method with a newborn animal model—the domestic chick. This method can be used to measure the development of newborn object recognition for extended periods of time in strictly controlled virtual environments. First, I describe controlled-rearing experiments demonstrating that newborn chicks have advanced object recognition abilities, including view-invariant recognition and background-invariant recognition. These abilities develop rapidly (within the first few days of life) and can emerge from sparse input (e.g., view-invariant object recognition can develop from a single view of an object). These findings indicate that newborn visual systems can be highly generative at the onset of vision. Next, I describe controlled-rearing experiments characterizing the role of visual experience in the development of object recognition. We have discovered that the development of object recognition requires at least four types of visual experience: (1) experience with slowly moving objects, (2) experience with smoothly moving objects, (3) experience with objects containing surface features, and (4) experience with objects on natural backgrounds. When chicks are reared in environments that lack these experiences, the chicks fail to develop accurate object recognition abilities. Finally, I describe how these controlled-rearing data can be linked to models of visual cortex for characterizing the computations and learning rules underlying newborn object recognition. I conclude that controlled rearing can serve as a critical tool for testing between different theories and models in the vision science and computational neuroscience communities.

Acknowledgement: NSF CAREER Grant BCS-1351892

55.16, *6:30 pm* High cellular and columnar variability underlies the absence of early orientation selectivity David Whitney[1](david.whitney@mpfi.org), Gordon Smith[1], Bettina Hein[2], Matthias Kaschube[2], David Fitzpatrick[1]; [1]Max Planck Florida Institute for Neuroscience, Jupiter, Florida, [2]Frankfurt Institute for Advanced Studies, Frankfurt am Main, Germany

Selectivity for stimulus orientation is a fundamental property of primary visual cortex in primates and carnivores, where it is organized into a smoothly varying columnar map that emerges in an activity-dependent manner during early postnatal life. Despite extensive experimental and theoretical work, it remains unclear what factors limit the emergence of orientation selectivity, such as weak responsiveness to visual stimuli, high trial-to-trial variability, and/or an intermixed 'salt-and-pepper' organization of orientation preferences at the cellular level. To distinguish between these potential factors, we visualized population activity in the visual cortex of developing ferrets with longitudinal imaging of GCAMP6s at both cellular resolution with two-photon calcium imaging and columnar resolution with wide-field epifluorescence imaging. Prior to eye opening, we show that cellular and population responses evoked by single presentations of a grating stimulus surprisingly exhibit robust, modular patterns of network activity resembling activity patterns evoked by gratings in mature animals. However, the spatial location and pattern of domains activated by presentation of the identical stimulus orientation varies substantially across trials, a variability that accounts for the low orientation selectivity of individual neurons and the inability to visualize coherent maps of orientation preference. Yet variability in network activity patterns is not a general feature of the developing cortex, as the modular patterns of network activity evoked by uniform luminance steps are already selective at these ages. Furthermore, we show that trial-averaged activity patterns evoked by gratings show similarity to the mature orientation map as early as 1-2 days prior to eye opening. We conclude that the early disassociation between stimulus orientation and consistent patterns of modular network activity is a major factor underlying the absence of orientation selectivity in a developing cortical network already exhibiting highly modular functional organization.

Acknowledgement: Max Planck Florida Institute for Neuroscience, Max Planck Society, National Eye Institute, Bernstein Focus Neurotechnology

55.17, *6:45 pm* **Tracking the recognition of static and dynamic facial expressions of emotion across life span** Anne-Raphaëlle Richoz[1](anne-raphaelle.richoz@unifr.ch), Junpeng Lao[1], Olivier Pascalis[2], Roberto Caldara[1]; [1]Eye and Brain Mapping Laboratory (iBMLab), Department of Psychology, University of Fribourg, Fribourg, Switzerland, [2]Laboratoire de Psychologie et Neurocognition (CNRS), Université Grenoble-Alpes, Grenoble, France

Dynamic social signals are steadily stimulating the visual system during human interactions. A wealth of such signals are transmitted as facial expressions for communicating internal emotional states. Unlike static snapshots, routinely used in most of the experiments, dynamic facial expressions provide observers with richer and ecologically-valid signals. Common intuition would thus suggest an advantage for the recognition of dynamic over static inputs. However, while many studies reported an advantage in the recognition of dynamic over static expressions in clinical populations (Richoz et al., 2015), results obtained with healthy young adults are by far more contrasted. To clarify this issue, we conducted a large sample cross-sectional study to investigate facial expression recognition from early to elderly age. Over 400 observers (age range 5-100) performed recognition tasks of the six basic expressions in three conditions: static, shuffled (temporally randomized frames) and dynamic (Gold et al., 2013). We normalized the stimuli for their low-level properties and the amount of energy sampled over time, even for the static condition. Facial expression recognition profiles revealed a better performance for "happy" and typical confusions among expressions with similar morphology (fear-surprise), regardless of condition and age. We then applied a Generalized Additive Model with smoothing spline on an efficiency index to capture the non-linear relationship between age and the experimental conditions. Overall, we observed strong efficiency in the recognition of dynamic facial expressions in the elderly population. This observation was driven by a suboptimal performance for static and shuffled expressions, a potential marker for impaired face processing that might be linked to other facets of general cognitive decline. Our findings also posit the use of dynamic stimuli as being critical in the assessment of facial expression recognition in elderly populations, inviting to caution when drawing conclusions from the sole use of static face images to this aim.

55.18, *7:00 pm* **The milk in the bathroom strikes again: ERP evidence for the processing of semantic object-scene inconsistencies in early development** Sabine Öhlschläger[1,2](oehlschlaeger@psych.uni-frankfurt.de), Melissa Vo[1,2]; [1]Scene Grammar Lab, Goethe University, Frankfurt, Germany, [2]Center for Research on Individual Development and Adaptive Education of Children at Risk (IDeA), Frankfurt, Germany

Our every-day world is not random, but governed by rules regarding which objects can be found where. Imagine finding a bottle of milk in your bathroom. This would be quite surprising to us. But when during development are the semantic predictions implemented that would yield such a 'surprise effect'? Tracking kids' eye movements in a previous study (VSS 2016), we observed their gaze to be stuck on semantically inconsistent objects in scene photographs by the age of three, which we interpret as indication of their developed semantic expectations regarding object-scene relations. But besides behavioral evidence, semantic violations in scenes can also be tracked at the neural level as expressed by an N400 effect in adults. In an EEG-experiment with gaze-contingent scene presentation we tested seven 2-year olds and eleven adults. First, a scene preview was presented, without the critical object. Then, the children's gaze was attracted by an animated cue to the scene position where the critical object would occur. Upon cue fixation, the object, which could either be consistent or inconsistent with the scene context, would appear at the corresponding location. Using this paradigm, adults showed a reliable negativity to semantic violations with a central topography in the time range 300-500 ms. For the 2-year olds, we observed a trend for such an N400 effect ($p = .07$) indicating that semantic expectations in visual scenes might already be implemented earlier than by the age of three. First revealed in language development, future research could profit from directly comparing the developmental trajectories of this semantic processing between both, the scene and language domain to understand shared and distinct underlying mechanisms and their links to inter-individual differences in linguistic and cognitive abilities. This knowledge could eventually feed into earlier diagnosis and therapy of language disorders even at a preverbal stage.

Acknowledgement: This work was funded by DFG grant VO 1683/2-1 to MLV.

Visual Memory: Working memory and persistence

Tuesday, May 23, 5:15 - 7:15 pm
Talk Session, Talk Room 2
Moderator: Duje Tadin

55.21, *5:15 pm* **Perceptual inefficiencies predict individual differences in working memory both in typical adults and in schizophrenia** Woon Ju Park[1,2](wpark6@ur.rochester.edu), Megan Ichinose[3], Sohee Park[3], Duje Tadin[1,2,4]; [1]Center for Visual Science, University of Rochester, [2]Department of Brain and Cognitive Sciences, University of Rochester, [3]Department of Psychology, Vanderbilt University , [4]Department of Ophthalmology, University of Rochester School of Medicine

Deficits in visual working memory (VWM) are well recognized in Schizophrenia (SCZ). However, the mechanisms associated with such impairments are unclear. Previous findings show that sensory processing may be involved in encoding stimulus features in VWM (Pasternak & Greenlee, 2005). Using an equivalent noise paradigm, we characterized the sources of noise that influence perceptual inefficiency, namely, internal noise and external noise filtering, and tested the hypothesis that noisier perceptual processing may be linked to impaired VWM in SCZ. METHODS: Participants (19 individuals with SCZ and 19 demographically matched neurotypical controls) performed two behavioral tasks, measuring sources of perceptual inefficiency and VWM precision. In the orientation discrimination task, participants judged the orientation of gratings (1 cycle/°; 1° radius; tilted ±45° from vertical) embedded in varying levels of external noise (0-21%). Contrast thresholds were measured, and modeled using the Perceptual Template Model (Lu & Dosher, 2008) to estimate the levels of internal noise and external noise filtering. In the VWM task, participants reproduced orientations of analogous gratings at 1s delay across different set sizes (1-4). VWM precision was estimated by fitting circular Gaussians on orientation errors. RESULTS: Individuals with SCZ showed increased internal noise and worse external noise filtering compared to controls. They also exhibited considerably worse VWM precision across all set sizes.

Importantly, external noise filtering predicted VWM precision in both groups. Internal noise was negatively correlated with VWM precision only in controls. CONCLUSION: We show evidence that perceptual inefficiencies may impact VWM precision in both neurotypical individuals and those with SCZ. The results further demonstrate noisier visual perception in SCZ. This provides broad implications, as noisy perceptual processing may play an important role in higher order cognitive and social deficits associated with SCZ.

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55.22, *5:30 pm* Perceptual grouping boosts visual working memory capacity and reduces effort during retention Candice Morey[1](C. Morey@ed.ac.uk); [1]Department of Psychology, School of Philosophy, Psychology, and Language Sciences, University of Edinburgh

Consistent and robust boosts to visual working memory capacity are observed when color-location arrays contain duplicated colors. It remains unclear exactly why this boost occurs. The prevailing hypothesis suggests that duplicated colors are encoded as one perceptual group. If so, then we should observe not only higher working memory capacity overall, but specifically an improved ability to remember unique colors from displays including redundancy compared with displays without redundancy. This hypothesis also suggests that less effort should be required to retain displays including duplicate colors. I recorded gaze position and pupil sizes during a visual change detection task including displays with all unique colors, two items with a common color, or three items with a common color. Increased redundancy was indeed associated with higher estimated working memory capacity, both for tests of uniquely-colored items and duplicates. Redundancy was also associated with decreased pupil size during retention, consistent with the hypothesis that encoding multiple items as a group eases memory for the visual array. I tested samples of young adults (19-33 years old) and healthy elderly adults (65-82 years old) in order to learn whether these benefits, which could depend on the ability to maintain color-location bindings, changed with age. Like young adults, elderly adults benefited from color redundancy, though their estimated working memory capacities were lower overall. However, more redundancy in the display was needed for elderly adults to show the same increases in capacity as young adults. The pupillometry data from the elderly adults likewise suggested that the impact of redundancy on effort was attenuated. Overall, these results support the contention that feature redundancy affords perceptual grouping, which reduces the amount of information to-be-maintained from a visual display.

55.23, *5:45 pm* Erasing and blurring memories: The differential impact of visual interference on separate aspects of forgetting Sol Sun[1,2](sol.sun@mail.utoronto.ca), Celia Fidalgo[1,2], Morgan Barense[1,3], Andy Lee[2,3], Jonathan Cant[2], Susanne Ferber[1,3]; [1]Department of Psychology (St. George), University of Toronto, [2]Department of Psychology (Scarborough), University of Toronto, [3]Rotman Research Institute at Baycrest Hospital

Visual interference is often conceptualized along a single continuum. Specifically, the widely held similarity assumption of interference states that as the similarity between interfering information and memory contents increases, so too does the degree of memory impairment. However, forgetting can manifest in different ways. For instance, studied content might be erased in an all-or-nothing manner. Alternatively, information may be retained but the precision of these representations might be degraded or blurred. Here, we asked whether the similarity of interfering information to memory contents might differentially impact these two aspects of forgetting (i.e., erasing vs. blurring). Observers studied colored images of real-world objects, each followed by a stream of interfering objects. Across 3 experiments, we manipulated the similarity between the studied object and the interfering objects in continuous, circular hue space. After interference, memory for object color was tested continuously on a color wheel, which in combination with mixture modeling, allowed for estimation of the separate contributions of erasing and blurring owing to forgetting. In contrast to the similarity assumption, across all 3 experiments we show that highly dissimilar interfering items were most likely to erase the contents of memory. However, highly similar and variable interfering items tended to blur or decrease the precision of representations, even though the studied information was still retained. These results reveal that the nature of visual similarity of interfering information can differentially alter the way in which items are forgotten from memory.

Acknowledgement: Natural Science and Engineering Research Council of Canada (NSERC), Canadian Institutes of Health Research (CIHR)

55.24, *6:00 pm* Stimulus Memorability as a Unique Determinant of Memory Independent from Attention, Priming Wilma Bainbridge[1](wilma.bainbridge@nih.gov); [1]Laboratory of Brain and Cognition, National Institute of Mental Health

Various forces influence what we ultimately remember – such as how attention-grabbing an image is, how much effort we put into remembering that image, or how primed we are for that image. Recent work has identified an intrinsic, high-level perceptual stimulus property – memorability – that is highly consistent across viewers and predictive of whether an image is likely to be remembered or forgotten. Can memorability effects be explained by these other phenomena, such as attention, known to influence memory? We explore this question through a series of psychophysical experiments using classical paradigms well-tested in the literature (i.e., visual search, directed forgetting, perceptual priming) but using face and scene images pre-determined to have high and low memorability. These stimuli are controlled for any possible confounds, including low-level attributes (e.g., color, spatial frequency) and high-level attributes (e.g., gender or emotion for faces; indoor/outdoor or number of objects for scenes). We find that memorability remains resilient despite manipulations of attention and priming: memorability does not cause automatic bottom-up attention capture; one cannot intentionally forget a memorable face or remember a forgettable face; and memorability and perceptual priming are two separate phenomena. In sum, these results provide evidence for memorability as an independent, intrinsic attribute of an image that works in conjunction with other phenomena such as attention and priming to determine if an event will be ultimately remembered.

55.25, *6:15 pm* Binding errors in long-term memory: Independent storage of different features of real-world objects Igor Utochkin[1](i-sutochkin@inbox.ru), Timothy Brady[2]; [1]National Research University Higher School of Economics, Russia, [2]University of California San Diego, USA

In 2012, Brady, Konkle, Alvarez, and Oliva showed that long-term memories of real-world objects are not stored as monolithic units. Different features of studied objects (e.g., an exemplar and its state) are forgotten independently, suggesting these features are not stored as a single bound unit. Here we test another implication of this unboundedness: If different object features are stored independently, they might "swap", producing false combinations of true features, even in real-world objects. In Experiment 1 (N=20), observers studied 120 categories of objects, each represented by two exemplars. These exemplars could be shown in either the same state (two full mugs) or different states (one full mug, one empty mug). After studying the items, participants were given a forced-choice recognition test where they had to choose the correct states of both exemplars. We found that participants were sensitive to whether the objects were in the same state: they chose the same states for both exemplars if the studied exemplars were shown in the same states (mean: 67%), but not if the exemplars have been shown in different states (mean: 36%). Importantly, while in the former condition the probability of choosing both correct states was above chance (57% vs. 25% chance), the probability of correctly choosing two different states in the latter study condition was at chance (29%). Thus, people remember the states presented in exemplar pairs but often fail to bind them correctly. In Experiment 2 (N=20), participants studied only one exemplar from each category and had to recognize this exemplar later, either when it was presented in a new state or its original studied state. Performance was same regardless of test state (80% vs. 76%). Together, our findings of swap errors and state-independent exemplar recognition support the idea of independent feature storage for real-world objects.

Acknowledgement: Program for Basic Research at NRU HSE in 2016

55.26, *6:30 pm* Neural representations of spatial position recalled from long-term and short-term memory diverge across the cortical hierarchy Vy Vo[1](vyaivo@ucsd.edu), David Sutterer[2,3], Joshua Foster[2,3], Thomas Sprague[4], John Serences[1,5,6], Edward Awh[2,3]; [1]Neurosciences Graduate Department, University of California, San Diego, [2]Department of Psychology, University of Chicago, [3]Institute for Mind and Biology, University of Chicago, [4]Department of Psychology, New York University, [5]Department of Psychology, University of California, San Diego, [6]Institute for Neural Computation, University of California, San Diego

Holding an item in short-term memory (STM) elicits stimulus-specific representations across sensory, parietal, and frontal cortex (Ester, Sprague, Serences 2015). Recent evidence suggests that retrieving items from long-term memory (LTM) also reinstates neural representations in sensory cortex (Bosch et al. 2014). However, it remains unknown how sensory representations of items from LTM and STM differ in their distribution across these areas of human cortex. Here, we directly compared neural representations of locations that were retrieved from LTM or maintained in STM, and assessed how these neural measures tracked behavioral precision. We trained subjects to associate 24 unique clip art items with spatial positions along an isoeccentric ring (Sutterer & Awh, 2015). In subsequent training days, subjects performed both a LTM task to retrieve the learned pairings and a STM task which required subjects to maintain a spatial position in STM. The precision of subjects' LTM recall plateaued after ~5 days of training, with precision that approached STM performance. We then acquired fMRI while subjects performed both tasks in the scanner. On separate runs, we obtained data to train an inverted encoding model (IEM) for spatial position. This allowed us to reconstruct the spatial location of each item as it was being held in memory (e.g., during a stimulus-absent delay period; Sprague et al. 2014; Ester et al. 2015). We successfully reconstructed the position of the remembered stimulus during the delay period of both tasks. STM representations were more robust than LTM representations in early sensory areas. However, the difference between the fidelity of STM and LTM representations decreased in later sensory areas. Overall, our data suggest that changes in the relative representations of items stored in STM and LTM across the visual hierarchy likely support the precision of LTM recall.

55.27, *6:45 pm* **Neurophysiological Marker of Visual Working Memory Manipulation** Hrag Pailian[1](hrag.pailian@gmail.com), Viola Störmer[2], George Alvarez[1]; [1]Department of Psychology, Harvard University, [2]Department of Psychology, University of California, San Diego

Previous research has discovered the neural correlates of visual working memory storage capacity (e.g., Vogel & Machizawa, 2004), but not the neural correlates of the defining feature of working memory – the manipulation of stored information. To this end, we recorded neural activity using electroencephalography (EEG) while observers completed a working memory (WM) manipulation task. Observers were cued to remember 3 colored circles on one side of the display (ignoring a perceptually matched display on the other side), followed by a maintenance period where the colors disappeared leaving behind placeholders. These events were succeeded by a placeholder-motion period, in which a pair of placeholders underwent smooth motion to swap locations. Observers were instructed to either update the spatial-featural bindings, keeping the features aligned with the moving placeholders (storage and manipulation) or to ignore the movement altogether and remember the features at their original locations (storage only). Observers subsequently identified the color of a cued item. We observed a sustained contralateral delay activity (CDA) at posterior electrode sites for both conditions during the initial maintenance prior to placeholder motion (representing the initial storage of information). This lateralized activity persevered into the placeholder-motion period, and remained active throughout this time window. The magnitude of the CDA did not differ between Update and Ignore conditions during either the initial maintenance period, $F(1,11)=2.31$, $p=.16$, or the placeholder-motion period, $F(1,11)=3.69$, $p=.08$. However, we observed a sustained nonlateralized negativity for Update trials, but not Ignore trials, at frontal-central electrode sites during the placeholder-motion period, $F(1,11)=7.13$, $p=.02$, but not during the initial maintenance period before movement, $F(1,11)=1.46$, $p=.25$. This negativity showed a bilateral anterior scalp distribution, focusing over frontal-central electrode sites. These results present the "Frontal-Central Negativity" as a candidate neurophysiological marker of visual WM manipulation, and suggest that storage and manipulation are separable cognitive and neural mechanisms.

55.28, *7:00 pm* **Working memory contents outside the focus of attention are represented by different neural populations not in an activity-silent state** Thomas Christophel[1-3](tbchristophel@gmail.com), Polina Iamshchinina[1-3], Chang Yan[1-3], John-Dylan Haynes[1-6]; [1]Bernstein Center for Computational Neuroscience, Charité Universitätsmedizin Berlin, [2]Berlin Center for Advanced Neuroimaging, Charité Universitätsmedizin Berlin, [3]Clinic for Neurology, Charité Universitätsmedizin Berlin, [4]Berlin School of Mind and Brain, Humboldt Universität zu Berlin, [5]Cluster of Excellence NeuroCure, Charité Universitätsmedizin Berlin, [6]Department of Psychology, Humboldt Universität zu Berlin

Some contents held in visual working memory are thought to be retained in a prioritized state typically referred to as the 'focus of attention', while other items are considered to be 'unattended', or 'accessory'. Attempts to identify and read out such unattended memory representations in the human brain using fMRI have so far only resulted in null findings, leading some to postulate that unattended items are retained in an 'activity-silent state', for example by synaptic mechanisms. Here, we revisited this important question to test an alternative explanation for previous null results: Attended and unattended items are retained by separate patterns of neural activity which might even be localized in different brain areas. In the experiment, participants memorized the orientation of two Gabor patches in an MRI scanner. A first cue, indicated that one of the two stimuli should be used for a first orientation change detection task making it the attended memory content for a first delay. After this first task, a second cue could select the other orientation for a second task, ensuring that participants had to maintain both orientations during the first delay. We analyzed fMRI data from this maintenance interval using cvMANOVA MVPA and a large set of regions of interest to independently identify information about the attended and the unattended item. Information about the attended orientation stored in working memory was found predominantly in V1, as well as inferior and superior parietal areas. Importantly, the information about the not prioritized or unattended working memory orientation was represented in the intraparietal sulcus within the same maintenance interval, where no information was found for the attended item. Finding separate representations of currently relevant and irrelevant working memories demonstrates separate activity-based storage mechanisms for attended and unattended items.

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 SEE PAGE 3 FOR ABSTRACT NUMBERING SYSTEM

Visual Search: Eye movements and memory

Tuesday, May 23, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

56.3001 Intrinsic Position Uncertainty and Clutter in Natural Search Tasks

Yelda Semizer[1](yelda.semizer@rutgers.edu), Melchi Michel[1]; [1]Rutgers University

Many studies have shown that position uncertainty impairs performance while detecting and discriminating a stimulus. However, few of these studies have specifically examined intrinsic position uncertainty (IPU), which cannot be directly manipulated. Instead, most investigations have focused on extrinsic position uncertainty (EPU), which can be manipulated. In a recent study, we developed an experimental technique that modulates the distribution of clutter in synthetic noise displays while keeping EPU fixed. Because clutter at irrelevant locations only degrades search performance via IPU, we were able to show how IPU limits performance for overt search in synthetic displays. In the current study, we investigated whether IPU similarly limits overt search performance in natural images. Observers completed a search task that required locating an object (e.g., a key) in a natural image representing the contents of a bag. At the start of each trial, observers saw cues representing potential target locations. After completing their search, they responded by reporting either the perceived location of the target (if it was present) or by reporting its absence. However, rather than imposing synthetic clutter, as in the previous task, we used an existing measure (Bravo & Farid, 2008) to quantify the clutter for a set of natural images. We then modulated the clutter distribution by assigning high clutter images to one condition and low clutter images to another. We independently varied the number of potential target locations to manipulate extrinsic position uncertainty (EPU). Finally, we manipulated target presence across images to examine its interaction with the amount of clutter. Our results show that the amount of clutter in natural images degrades search performance irrespective of EPU, suggesting that IPU limits performance for overt search in natural images.

Acknowledgement: NSF BCS1456822

56.3002 The Effects of Unique Blur/Clarity Contrast on Visual Selective Attention as Measured by Eye Movements: Strong Clarity Capture and Weak Blur Repulsion

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Blur has previously been suggested to be processed preattentively (Loschky et al., 2014). Blur may be responded to in a similar fashion to other preattentive features such as color, orientation, size, etc., which can capture attention leading to 'pop out' (Treisman & Gelade, 1980). However, previous eye-tracking studies have found that when blur/clarity contrast exists in an image, eye-movements are typically directed towards regions of clarity and ignore blurred regions (Enns & MacDonald, 2012; Kahn, Dinet, & Konik, 2011; Loschky & McConkie, 2002; Smith & Tadmor, 2012). Peterson (2016) showed in a rotated L and T visual search task that uniquely blurred letters were ignored by selective attention, but uniquely clear items captured attention, as shown by reaction time results. The current study added eye-tracking to the methods used in Peterson (2016) to investigate if the previous reaction time results were an effect of unique blur being either ignored or repelling attention at the start of a rotated L versus T visual search. Set sizes of four and eight letters were used. Letters were presented on an imaginary circle of eight degrees radius. Uniquely blurred and clear singleton letters were manipulated to be nonpredictived of target location. Similarly to the results of Peterson (2016), reaction times at both set sizes (4 & 8) suggested that blur is ignored by selective attention. However, investigation of the first letter fixated in the visual search showed that uniquely clear letters strongly captured attention, while uniquely blurred letters weakly repelled attention at each set size. These findings suggest that overall reaction times are not sensitive enough to detect the weakly repulsive nature of blur to selective attention, but with eyetracking we have found evidence to suggest that unique blur repels, though not nearly as strongly as attention is captured to uniquely clear letters.

56.3003 We know what we can see - peripheral visibility of search targets shapes eye movement behavior in natural scenes

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Influences of target features on fixation locations and search durations have been widely studied. What happens to properties of the eyes' scanpath when looking for different targets has not been investigated as thoroughly. One important target aspect is how far into the periphery it is detectable, which can be varied by changing its spatial frequency content. Here we show that human participants adapt their eye movement behavior immediately when searching for different targets in natural scenes. In our study, participants searched natural scenes for 6 artificial targets with different spatial frequency content. High spatial frequency targets led to shorter fixation durations and smaller saccade amplitudes than low spatial frequency targets. The effect of the smaller saccade amplitudes appeared from the first of eight experimental sessions, without training, persisted throughout all sessions and disappeared when subjects were not told which of the targets to search for. Fixation durations were shorter for high spatial frequency targets after one training session, also persisted throughout all subsequent sessions and disappeared when subjects were not told which of the targets to search for. The differences in eye movement patterns between low and high spatial frequency targets led to longer search times to find the high frequency targets, but the probability to find the target within 10 seconds was unchanged. As high spatial frequency targets can not be detected far into the periphery, it is adaptive to choose a scanning strategy with shorter fixation durations and shorter saccade amplitudes when searching for high spatial frequency targets. Our results suggest that humans are capable to adequately adapt their eye movement behavior instantaneously according to the spatial frequency content of the target, implicitly adapting to how far from the fovea targets can be detected.

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56.3005 Visual saliency and ensemble work simultaneously on eye movement in visual search

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The more salient point of a scene, the more it attracts visual attention. A saliency-based visual attention model can simulate human eye movement. While saliency is computed from local information, ensemble is computed from spatially distributed objects. Human can also immediately get global information of the scene as ensemble information. However it remains unclear whether ensemble is used for visual search. The research questions are whether, when and how saliency and ensemble affect human search process. Our prior research suggests that eye movements depend primarily on saliency at first and ensemble gradually affects them after a few saccades. Gabor patches were placed as targets in the left and right side of the screen. The task was to count the point of Gabors distributed on pink-noised background and judge which side of the screen included just 20 points, during which their eye movements were recorded. In each trial, among white Gabors with 1 point, there was only one colored (the most salient) Gabor with 2 or more points, in the side with 20 points (congruent condition), or in the side with less than 20 points (incongruent condition) and the difference in points between the left and right sides were manipulated. Since the saliency of colored Gabor includes both physical and value components, the value of colored Gabor may be responsible for the higher saliency at the initial stage. To examine this possibility, the current experiment used all Gabors with equal point (1 point), and now there was no initial advantage of colored Gabor over ensemble information, in that the direction of the first saccade is not significantly different from chance level in the incongruent condition. It suggests that visual saliency and ensemble work simultaneously when the salient object has an equal value. This work was supported by JSPS KAKENHI grant #16H01506 and #16H01727.

Acknowledgement: Ensemble

56.3006 Is efficiency of difficult visual search determined by dwelling, skipping, and revisiting, rather than by guidance by the target?

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Popular models of overt and covert visual search focus on explaining search efficiency by visual guidance. Visual guidance integrates information from the target template and potential target stimuli to prioritize probable target locations for selective processing. That some searches are fast whereas other searches are slow is explained by the ability of the target to guide attention to the target's position. Comparably little attention is given to other variables that might also influence search efficiency, such as dwelling on distractors, skipping distractors, and revisiting distractors. Here we test the relative contributions of dwelling, skipping, rescanning, and the use of visual guidance, in explaining visual search times, and in particular the similarity effect. The similarity effect is the more efficient search for a target that is dissimilar from the distractors compared to a target that is similar to the distractors. In the present experiment, the experimental task is to find an emotional face target among nine neutral face non-targets. In different blocks, the target is either more or less similar to the non-targets. Eye-tracking is used to separately measure selection latency, dwelling on distractors, and skipping and revisiting of distractors. As expected, visual search times show a large similarity effect. Similarity also has strong effects on dwelling, skipping, and revisiting (but not on visual guidance). Regression analyses, conducted on both the condition and the trial level, further confirm these findings. Overall, results show that with complex stimuli like faces, target-distractor similarity influences search times primarily via the time gaze dwells on the non-targets and to a somewhat lesser degree by altering the proportion of revisited non-targets in the course of search. Measures of attentional guidance contributed relatively little to the similarity effect.

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56.3007 Comparing visual search for categories defined with an explicit versus implicit rule

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Categorical search guidance improves with the specificity of the categorical target designation (boots versus footwear), though guidance does not improve to the level observed with a pictorial preview, suggesting a benefit of knowing the exact target features (Maxfield & Zelinsky, 2012; Schmidt & Zelinsky, 2009). However, categories can be learned explicitly (e.g., categories separated along a single feature dimension) or implicitly (e.g., categories separated along a multidimensional bound requiring integration of features; Ashby, Alfonso-Reese, Turken, & Waldron, 1998). It is unclear how natural categories, such as those used in previous categorical search studies were learned, thus we investigated whether category rule type affects search performance. Participants learned to categorize sinusoidal gratings varying in spatial-frequency and orientation using either an explicit or implicit learning rule. Participants then completed a search task in which targets were cued categorically or pictorially prior to a four item search array in which eye movements were recorded. We found a significant interaction between category rule and search cue type across a number of search measures including RT, the time until the first fixation on the target, the proportion of initial search saccades directed at the target, and the time required to verify target identity (all $p < .05$). In general, explicitly learned categories produced stronger search performance when cued categorically, however, the benefit of a pictorial preview depended upon both the category rule and the feature dimension. Categories defined implicitly or explicitly (in the orientation dimension) showed a large pictorial preview advantage, whereas categories defined explicitly (in the spatial-frequency dimension) showed little benefit. This suggests non-linear relationships between the target representation (categorically or pictorially derived) and search performance; the benefit of knowing the exact target features is affected by the category rule and feature dimension.

56.3008 Evaluating the Importance of Top-Down "Semantic" Features to Decoding Observer Task from Eye Movements

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Since Yarbus (1967), there has been considerable debate over the influence "top-down" factors, such as scene knowledge or task, have on eye movement behavior. Many studies have therefore attempted to decode some feature of an observer's cognitive state from their eye movements. However, until recently, it has been challenging to embed such "high-level" information directly into images, so few studies have examined the potential role that top-down scene or task features could play in a decoding procedure designed to infer attributes of the observer's cognition. We evaluated the importance of a novel set of such high-level features with respect to the performance of a classifier built to decode an observer's task during natural scene inspection. This was achieved by asking subjects to perform one of three tasks while viewing each of 210 natural scene images taken from the LabelMe image database: free viewing, object counting, and inspection made in preparation for a written description of the scene For each subject/trial pairing, three types of features were computed: eye movement features, image salience features of inspected objects and of the entire scene, and a novel set of "semantic" features. These latter described the semantic relatedness of all labeled objects within a scene between themselves, between themselves and a scene gist label, and between the objects sequentially inspected by the subject. Semantic relatedness was calculated using cosine similarity values within a shared vector-space language model (word2vec, Mikolov et al., 2013). A random-forest classifier applied to this data achieved significantly above chance levels of accuracy. Variable importance measures rated these semantic features as among the most important to classifier performance. We therefore suggest that these or similar features should be computed and used in studies that aim to infer an observer's cognitive state from the pattern of their eye movements in a scene.

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56.3009 Low target prevalence exacerbates problems with Computer-Aided Detection (CAD) during visual search

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Computer-aided detection (CAD) is widely used in medical screening tasks. While the technology holds great promise and computer algorithms continue to improve, the benefits of CAD are remarkably small in practice. In fact, recent work has shown that the presence of CAD in mammography screening clinics resulted in no net benefit (Lehman et al., 2015). Previous work investigated this surprising result by creating a visual search task that emulates important aspects of screening mammography: difficult to detect 'targets' embedded in 1/f noise (Drew et al, 2012). They found that while CAD led to a small behavioral benefit, it also led to significant costs. In particular, targets that were missed by the CAD algorithm were missed at a very high rate, and eye-tracking measures suggested that this may have been driven by less complete search in the presence of CAD. However, targets occurred in this study at a high prevalence while targets in screening mammography are extremely rare. It not currently known how target prevalence influences how CAD is used. In order to investigate this gap in our understanding, observers completed blocks of trials at both high (50%) and low (10%) prevalence. Replicating previous work, low prevalence led to shorter response times and lower hit rates. Our eye-tracking measures of coverage demonstrated reduced coverage in the CAD condition, irrespective of target prevalence. There was a significant interaction between CAD presence and prevalence on hit rate such that targets that were missed by the CAD were much more likely to be missed in the low prevalence block of trials. While helpful in theory, the benefits for CAD in practice are mixed. This work shows that this may be a result of the costs of CAD being exacerbated at low target prevalence.

Acknowledgement: DOD: W911NF-07-2-0055

56.3010 **Visual foraging with two simultaneous visual working memory templates**
Tómas Kristjánsson[1](tok1@hi.is), Ian Thornton[2], Árni Kristjánsson[1]; [1]Department of Psychology, University of Iceland, [2]Department of Cognitive Science, University of Malta

A key assumption in the literature on visual attention is that templates, corresponding to targets, are actively maintained in visual working memory (VWM) during visual search. Guiding visual attention is in fact often considered one of the main functions of VWM. According to a recent influential theory, only one search template can be active within visual working memory at any given time, while other templates have the status of accessory templates – they are accessible, but do not interact with visual attention. This account makes the clear prediction that switch-costs should always occur when targets change between attention deployments. An alternative account argues against this, claiming that more than one search template can be active at the same time and that the number of active templates is determined by attentional load rather than a precise number of templates. Using a novel iPad foraging task, where participants search for multiple targets from two categories, we measured the effects of switching between two categories. During foraging for disks of two colors among distractor disks of two different colors (feature foraging), observers quickly switched between simple target categories. Conversely, switch costs were an order of magnitude larger when the targets were distinguished by conjunctions of features. Rapid, effortless switching between target categories during feature foraging casts serious doubt on the claim that only a single search template can be active at any given time. While it is possible that the results reflect rapid alternations of a single active template, there is evidence that such template switching should take ~150-200 ms while switch costs during feature foraging were only between 20 and 40 ms. Overall, the results accord well with load theories while single-template accounts of VWM cannot satisfactorily explain the findings.

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56.3011 **Repetition Priming Preferentially Benefits Infrequent Targets**
Paul Scotti[1](paulscotti@gwu.edu), Stephen Adamo[1], Stephen Mitroff[1], Sarah Shomstein[1]; [1]Department of Psychology, The George Washington University

The process of searching for targets among distractors (i.e., visual search) is affected by a wide array of factors. One known factor is that search performance is improved if a previous search trial contained the same target as the current trial, a phenomenon referred to as repetition priming. Repetition priming has been observed in both pop-out search (e.g., Maljkovic & Nakayama, 1994) and conjunctive search (e.g., Becker, 2008; Kristjánsson & Driver, 2008), yet, much remains unknown about the robustness of this phenomenon. For example, previous instantiations of repetition priming have primarily used small sets of possible targets and distractors. The current investigation used a large array of possible targets and distractors in a complex search environment to test the limits of repetition priming and to explore novel factors that might affect it. Data were drawn from the mobile technology app Airport Scanner (Kedlin Co., www.airportscannergame.com), a game wherein players search for prohibited items in simulated images of XRAY baggage. This is an ideal dataset for the current purposes given there are billions of individual trials, millions of unique users, and hundreds of distinct target types. The current study examined whether (1) repetition priming persists across many different targets that range in color, size, and shape; and (2) if individual target frequency (i.e., how often a specific target appears in search) modulates the priming effect. Repetition priming was observed; a target was detected faster if the previous search display contained the same target as opposed to a different target. Target frequency modulated this effect, whereby rarer targets benefitted more from repetition priming. These results suggest that repetition priming has direct consequences for complex searches, such as baggage screening, and that repeated exposure to specific targets attenuates this effect.

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56.3012 **When searching for two targets takes twice as long as one**
Travis Weaver[1](Travis.p.weaver@vanderbilt.edu), Hyunyoung Park[1], Julianna Ianni[1], Geoffrey Woodman[1]; [1]Department of Psychology, Vanderbilt Vision Research Center, Vanderbilt University

Theories of visual attention suggest that we hold attentional templates of targets in visual working memory to help guide attention. However, our recent research shows that the attentional template that guides attention moves from visual working memory to visual long-term memory when the target object is repeated across multiple trials. This is shown by measuring two event related potentials (ERPs); the contralateral delay activity (CDA), which is a measure of visual working memory storage, and the anterior P1 and FN400, measures of visual long-term memory storage. By measuring these electrophysiological indices and behavior across trials of searching for the same target, we can estimate how rapidly people switch between using visual working memory to using visual long-term memory to control attention. In the current experiment, we tested the hypothesis that this transition to relying on visual long-term memory to control attention can operated simultaneously when we are asked to search for two different targets across trials. If this is the case, we should find that the CDA decreases to asymptote just as rapidly when searching for one or two targets across trials. We had subjects search for either one or two Landolt-C stimuli across runs of trials while recorded their ERPs. Subjects' ERPs show that the transition from visual working memory to visual long-term memory took twice as long when people were searching for two targets across trials compared to when they searched for one. These findings suggest that tuning attention to select multiple possible targets may have capacity limits itself.

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56.3013 **Decoding visually complex Chinese Characters during short-term memory from language related regions**
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There are conflicting ideas about the neural basis of short-term memory (STM) storage. Recent neuroimaging studies using multivariate pattern analyses (MVPA) reported evidence for visual STM storage of gratings, colors, motion and even complex visual patterns in content-selective occipital and parietal regions, which provides evidence against the classical model of predominant STM storage in prefrontal cortex. Here we studied how Chinese Characters are encoded in the human brain during short-term memory. Chinese characters have a simple pronunciation (one syllable per symbol) but also a complex visual appearance, which strongly encourages the use of verbal memorization strategies. In each trial, Chinese native speakers were instructed to memorize one out of two characters using a retro-cue. After a prolonged delay, they were tasked with identifying this character amongst a series of partly obscured test characters. Questionnaire data provided evidence for the predominant use of verbal strategies. Patterns of fMRI activity during maintenance were analyzed using searchlight-based MVPA (cvMANOVA) to identify brain regions encoding content-specific information about Chinese symbols. We found three brain regions containing significant stimulus information during the delay: the anterior Broca's area (ABA), the left premotor cortex (lPMC), and early visual cortex (EVC). EVC, however, also showed similar levels of information for not remembered stimuli indicating no involvement in memory storage. Both ABA and lPMC were lateralized to the left hemisphere and showed little content-specific information regarding other complex visual stimuli like color or motion patterns. ABA, but also left lPMC, have been previously implicated in language comprehension and production. In summary, our study provided evidence for verbal STM storage of Chinese symbols in language-related regions, which supports a distributed network model of STM storage and might constitute the neural substrate of Baddeley's 'phonological loop'.

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56.3014 **Spatial working memory in the absence of awareness**

Michael Payton[1,2](michael.payton@nyu.edu), Israr Ul-Haq[1], Kinza Maxood[1], Vahan Babushkin[1], Amber Nomani[1], Kartik Sreenivasan[1,3]; [1]Department of Psychology, New York University Abu Dhabi, [2] Department of Psychology, New York University, [3]Department of Biology, New York University Abu Dhabi

Can working memory (WM) exist outside of conscious awareness? Previous reports of 'unconscious' WM have been challenged on the grounds that above-chance performance could result from a superposition of (i) random guesses in the absence of awareness and (ii) accurate responses with subthreshold awareness. We addressed this possibility using a visuospatial delayed estimation task. In Experiment 1, we presented a colorful dot at a random location around an invisible annulus and instructed subjects to maintain the position of this dot across a brief delay. At the end of the delay, they reported the position of the dot with a mouse click. Experiment 2 was identical, except that we presented a line during the second half of the delay and had subjects mentally mirror the remembered location across this line before reporting this mirrored location. Across trials, we manipulated the visibility of the dot using backward masking: the dot was either masked after 16.7ms (suppressed trials), 50 ms (non-suppressed trials), or absent altogether (absent trials). Subjects rated their perception of the dot on each trial using a 4-point scale. We analyzed suppressed trials that were given the lowest perceptual rating (matching the perceptual rating of absent trials) and estimated subjects' WM precision from their memory reports using a standard mixture model. Even when they were unaware of the dot, subjects were able to report its location with a surprising degree of precision. This result held for Experiment 2, demonstrating that it is possible to manipulate WM representations without awareness. Most critically, we show through simulations that these data could not have resulted from the superposition of trials with no information and trials with subthreshold awareness. These results confirm that WM is possible without awareness and that it shares several properties with conscious WM.

VISUAL SEARCH: MODELS AND MECHANISMS

Tuesday, May 23, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

56.3015 **Improved Detectability Model Better Predicts Fixation Search in Natural Scenes**

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Previous work derived the optimal strategy for fixation search in stationary noise, for observers limited by the human detectability profile across the visual field1. In simulating search performance, the background's effect on detectability was represented as an equivalent input noise corresponding to the measured human detectability profile. While this procedure is appropriate for modeling search in stationary noise backgrounds (like white or 1/f noise), we found it is not appropriate for search in natural backgrounds. Specifically, we considered two targets: a 6 cycle/degree Gabor and a difference of raised cosines (DRC). For both targets, we measured detectability (with target location known) across the visual field in humans, and showed that a descriptive model, which includes local contrast-normalization, predicted detectability in Gaussianized natural backgrounds (backgrounds adjusted to have a Gaussian gray-scale histogram). Both targets had similar detectability profiles and were therefore predicted by the equivalent-noise simulations to be comparably difficult for human observers in a fixation search task. However, we found that search was much slower and less accurate (higher false-alarm rate) for the DRC target. Subjectively, this occurred because the natural backgrounds contained more false targets—locations with phase structure similar to the target. The false targets had a negligible effect in the simple detection task, because false targets are generally quite rare. However, even a handful of false-target locations can have a big effect in a search task. We extended the descriptive model of detectability to take into account local phase structure. Specifically, we partitioned the descriptive model of detectability into two components: a parameter-free matched-template detector and a retinal-location-dependent equivalent noise. The improved model correctly predicts the same detectability profile as before, and now also correctly predicts the much slower and less accurate search for the DRC target. 1Najemnik, J., and Geisler, W.S. (2009) Vis. Res., 49, 1286-1294.

56.3016 **The Interaction of Target-Distractor Similarity and Visual Search Efficiency for Basic Features**

Calden Wloka[1,2](calden@cse.yorku.ca), Sang-Ah Yoo[2,3], Rakesh Sengupta[1,2], John Tsotsos[1,2]; [1]Department of Electrical Engineering and Computer Science, York University, [2]Centre for Vision Research, [3]Department of Psychology, York University

Visual search efficiency is commonly measured by the relationship between subject response time (RT) and display set size. Basic features are visual features for which a singleton target can be found efficiently (RT independent of set size), a situation commonly referred to as pop-out. However, the seminal work of Duncan and Humphreys (1989) demonstrated that visual search RT is also correlated with the degree of target-distractor similarity. As similarity of the target with its surrounding distractors increases (and thus the target becomes more difficult to distinguish) RT can dramatically increase. Wolfe (1998a) identified this category as hard feature search, but left both an in-depth analysis of the transition from standard feature search to a hard search as well as the efficiency of hard search largely unexplored beyond a small number of orientation trials. As far as we are aware, the interaction of these two independent factors remains relatively unstudied. For colour and size, two basic features identified by Wolfe (1998b), we systematically vary target-distractor similarity and set size to develop a well-characterized psychometric function across both dimensions. This allows us to explore if there is a transition from efficient to inefficient search, or if even hard feature searches are still efficient when performed over a basic feature difference. We find that the relationship between target-distractor similarity and search efficiency is more complicated than a direct transition to inefficient search as the search grows hard.

Acknowledgement: The Canada Research Chairs Program, the Natural Sciences and Engineering Research Council of Canada and the Air Force Office for Scientific Research (USA)

56.3017 **Temporal organization of color and shape processing during target detection in conjunctive visual search**

Joseph Glavan[1](glavan.3@wright.edu), Joseph Houpt[1]; [1]Department of Psychology, College of Science and Mathematics, Wright State University

In many visual search paradigms, the target object is differentiated from distractor objects by multiple feature dimensions (i.e. conjunctive search). Process models make assumptions about whether these feature dimensions are processed in serial or parallel, but in practice it can be difficult to directly determine this temporal organization using conventional statistical methods. Systems Factorial Technology provides nonparametric statistics for distinguishing serial processing from parallel processing using selective manipulations of feature influence. In a previous study, we detected highly facilitatory, parallel processing in the target-absent condition of conjunctive search, but we failed to achieve selective influence in the target-present condition, precluding any conclusion of serial or parallel organization. Attributing this outcome to the uncertainty of the extent to which the participant must scour the display before locating the target and terminating their search, we repeated our previous experiment while eye tracking and mouse tracking in order to acquire other critical latencies, such as target and distractor fixation onsets and durations, which may be less sensitive to this confound. Participants were presented with a field of randomly positioned stimuli made from the conjunction of three possible colors (red and two shades of magenta) and three possible shapes (circle, octagon, diamond). The relative prevalence of a particular distractor changed across trials to manipulate the duration of color and shape processing within-subjects. Participants were instructed to indicate the presence of the target by moving the mouse to click on it. We replicated our previous results in terms of accuracy and response times, observing selective influence and evidence for parallel processing in the target-absent condition and failures of selective influence in the target-present condition. Furthermore, fixation onsets and durations were not selectively influenced, suggesting these intervals are not sensitive to the manipulation of stimulus prevalence. Implications for stage models of visual search are discussed.

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56.3018 **Variation of primary target contrast supports independence between race components in a search-step task**

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Tuesday PM

Performance in stop-change tasks has been modeled with both interactive and independent race models: the accumulator related to the first goal (GO1) either influences (interactive) or has no impact on (independent) the processes corresponding to the second goal (i.e., STOP and GO2). Here, to lend credence towards either model, we aimed to assess whether variations in GO1 influence STOP and GO2 through manipulating primary target contrast. In the present study, we recorded eye movements in two search-step experiments. Following the appearance of a luminance pop-out target amongst three distractors, participants were instructed to make an eye movement towards either the darkest (Experiment #1) or brightest (Experiment #2) stimulus as quickly as possible. In both step and no-step trials, the primary target (GO1) had variable contrast: either low (5%), medium (30%), or high (90%). However, on step-trials, following a random delay (83- 200 ms), the target changed position (GO2) and was set to low contrast. Primary target contrast significantly modulated saccade latency in no-step trials and in step-trials, non-compensated saccade latency. Conversely, this manipulation did not significantly change compensated saccade latency. These findings support the existence of an independent architecture. The changes in no-step and non-compensated saccade latencies (GO1) are predicted by either model via faster accumulation; however, compensated saccade latencies are expected to increase with contrast in the interactive model via increased inhibition from GO1 on GO2. The estimated target step reaction times also discounted a GO1-STOP interaction: they decreased with increases in primary target contrast. In conclusion, the current paradigm provides a method to test predictions regarding the alteration of race model parameters.

56.3019 Modeling the Influence of Visual Priming in Feature and Conjunctive Search

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When people look through the environment their eyes are guided in part by what they have recently seen. This phenomenon, referred to as visual priming, is studied in the laboratory through manipulations of stimulus repetition. Typically, in search tasks, response times are speeded when the same target is repeated relative to when it is changed (e.g., Maljkovic and Nakayama, 1994). Although priming is thought to be based on a memory mechanism in the visual system, there is a debate in the literature as to whether such a mechanism is driven by relatively early (e.g., feature-based accounts) or later (e.g., episodic memory accounts) processing. Across three experiments, this study utilized a computational modeling framework (Systems Factorial Technology; Townsend and Nozawa, 1995) to directly compare early and later accounts of priming and determine when visual priming influences processing within the visual system in both feature and conjunctive search tasks. Specifically, the processing of priming was assessed in terms of its temporal relation (i.e., parallel or serial) to a relatively early process (conspicuity) and a relatively later process (Rewards, Experiment 1a; Word Cues, Experiments 1b and 2) in the visual system. Results suggest that priming is processed in parallel with conspicuity and word cues within both singleton (Experiments 1a and 1b) and conjunctive (Experiment 2) search. This supports accounts of priming as an early process and suggest that models of priming as a later process within feature or conjunctive search should be rejected. Further, these results also provide evidence to suggest word cues are processed at early stages of visual processing. This supports models of visual processing that suggest high-level representations can modulate the earliest levels of the visual system. Together, these findings provide some of the strongest evidence about the temporal processing characteristics of priming to date.

56.3020 Evidence for a common decision mechanism for target-present and target-absent responses in visual search

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BACKGROUND: Visual search behavior is influenced by target prevalence. Wolfe & Van Wert (2010) found that, whereas target-absent response times (RT) and decision criterion varied with prevalence, target-present RT and overall sensitivity (d') did not. These results support a model that assumes target prevalence to influence two relatively distinct search processes. The first process governs the acceptance / rejection of each attended item. The second process governs the timing for terminating search with a target-absent response. PRESENT STUDY: The present study examines two tenets of this model. First, as the model predicts that target prevalence independently exerts its effects on decision criterion and target-absent RTs via different paths, the sizes of the two effects should be independent. In Experiment 1, I asked participants to search for an oriented line among vertical lines, manipulated target prevalence (20% vs. 80%), and measured decision criterion and target-absent RT. Contrary to the model's prediction, prevalence effects on the two measures correlated across participants ($r=0.545$, $p=.013$), indicating that the two processes are not entirely independent. Second, the model predicts that prevalence has no effect on target-present RT, because prevalence affects only the per-item decisions, but not the inspection duration for each search item. Indeed, most studies did not find this effect (with some exceptions), possibly because the effect was small and went undetected. In Experiment 2, I attempted to magnify this effect by adding orientation variations to the distractors, so that they became more confusable with the target. The result now showed a significant target-prevalence effect on target-present RT ($p=.019$). CONCLUSION: Taken together, the present results indicate that target prevalence affects both target-present and target-absent decisions, suggesting that both decisions may be governed by a common decision process. In my presentation, I will outline a decision mechanism that supports both response types and accommodates existing findings.

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56.3021 Satisfaction in Motion: Moving Search Displays Increase Subsequent Search Misses

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When searching for two or more targets, people are more likely to miss a second target after having found a first one (a subsequent search miss). This may be due to a depletion of cognitive resources from tracking the location of the first target. Given that tracking moving objects is resource-demanding, would finding a moving target further increase our chances of missing a subsequent one? This is an important question, as many real-world scenarios involve searching for moving objects (e.g., police searching for suspects in a crowd). Participants searched displays containing one or more targets hidden among a number of distractors and clicked on any targets they found. For some participants, targets and distractors moved randomly throughout the display. For others, targets and distractors always remained stationary. Critically, the probability of missing a second target increased by 50% in moving compared to non-moving displays. In a second experiment, we assessed whether this effect was due to participants allocating resources to tracking the first target. Participants searched the same moving or non-moving displays, but for some participants, any found targets were highlighted in a different color to facilitate tracking them. When found targets were not highlighted, the probability of missing a second target increased by 31% in moving compared to non-moving displays. However, when found targets were highlighted, the probability of missing a second target only increased by 3%. Together, these results suggest that our likelihood of missing a second target after finding a first one increases in dynamic search environments. This is likely due to the increased difficulty that comes from tracking the location of the first found target. More broadly, these results suggest that searching for multiple targets is demanding in terms of cognitive resources, and that subsequent search misses occur when these resources are depleted.

56.3022 Occipital and parietal cortex encode representations of match between a viewed and sought object during visual target search

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During a visual target search task, a stored representation of a search object is continually compared to a sensory representation of a currently-viewed visual scene. This comparison is likely to be performed through feedback modulation of sensory responses in higher visual areas, resulting in a representation of a variable encoding the conjunction between the viewed and sought objects (i.e. a "match" or decision signal) (Pagan, Urban, Wohl, & Rust, 2013). To investigate the evolution of this "match" representation in human cortex, we trained subjects to perform a visual matching task using Fribble object stimuli. A set of 8 objects was used for both the sought and viewed object, so that each of 64 possible sought object/viewed object combinations was sampled. We used multiband 3T BOLD fMRI to record changes in activation in visual occipital and parietal cortex while subjects performed this task. We used a linear support vector machine classifier, trained on activation patterns in each independently-defined ROI, to decode the identity of the viewed object, as well as the presence of a match between the viewed and sought objects. Within several regions of early visual cortex, we found that decoding of the viewed object was above chance, while decoding of an item's status as a match was at chance levels. In contrast, in several higher visual regions in ventral and lateral occipital cortex, we found that the viewed object could not be decoded, but the presence or absence of a match could be decoded with above-chance accuracy. These results suggest a transition across the ventral visual stream from predominantly stimulus-driven representations to abstract representations of task variables.

56.3023 Learning to shield visual search from salient distractors: Evidence from the N2pc component Marian Sauter[1,2](marian.sauter@psy.lmu.de), Heinrich Liesefeld[1], Hermann Müller[1,3]; [1]Department of Psychology, Ludwig-Maximilians-Universität München, Munich, Germany, [2]Graduate School of Systemic Neurosciences, Ludwig-Maximilians-Universität München, Munich, Germany , [3]Department of Psychological Sciences, Birkbeck College, University of London, London, UK

In visual singleton search, interference by salient distractors can be more efficiently shielded in locations where they appear more frequently (Goschy et al, 2014). In a previous study, we found that this probability cueing effect originates from spatial suppression, which is heavily modulated by the dimensional relationship between distractor and search target (Sauter et al., submitted). In the present study, we aimed to reveal a neural correlate of this suppression using electroencephalography. Fifteen subjects searched for a slightly left or right tilted target bar among 59 vertically oriented bars. In half of the trials, one of the non-targets was a horizontal 'distractor' bar. Crucially, when a (same-dimensional) distractor appeared, it appeared 90% of the time in either the top or bottom half of the search display (counterbalanced across participants). On distractor-present trials, either the distractor or the search target was displayed on the vertical midline. We analyzed the N2pc, an event-related potential that appears strongest at the parietal-occipital electrode sites PO7/8 contralateral to the attended stimulus and is thought to reflect attentional selection by mechanisms of distractor suppression. The results show that for distractor-present trials (1) reaction times are lower when a distractor appears in the frequent distractor area and (2) the N2pc yields a higher amplitude for distractors that appear in the frequent as compared to the rare distractor area; for distractor-absent trials (3) reaction times are lower when a target appears in the frequent distractor area and (4) the N2pc also yields a higher amplitude for targets that appear in the frequent as compared to the rare distractor area. This is indicative of the higher degree to which distractor suppression is recruited in the frequent distractor area due to learned shielding and supported by the role of the N2pc in top-down attentional mechanisms.

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56.3024 Functional roles of alpha oscillations underlying the communication between dorsal and ventral visual areas Sorato Minami[1,2](minami@fbs.osaka-u.ac.jp), Hiroki Oishi[1,2], Hiromasa Takemura[1,2,3], Kaoru Amano[1,2]; [1]Center for Information and Neural Networks, National Institute of Information and Communications Technology, [2]Graduate School of Frontier Biosciences, Osaka University, [3]Japan Society for the Promotion of Science

While alpha oscillations modulate various aspects of visual processing, their functional roles in visual perception are unclear. Our previous study (Minami and Amano, VSS2016) showed a tight relationship between alpha oscillations and an illusory jitter, called the motion-induced spatial conflict (MISC; Arnold & Johston, 2005). The MISC is a phenomenon where moving borders defined by color contrast are perceived to be jittering when they are placed in close proximity with those defined by luminance contrast. This enables us to study the mechanisms underlying the interaction of motion and shape processing. To further understand the mechanisms of alpha oscillation involvement in illusory jitter perception, we examined the relationship between the characteristics of alpha oscillations and the functional/structural property of dorsal-ventral communication in the visual cortex. In the first experiment, MEG responses were measured during illusory jitter perception, and the changes in both alpha power and alpha coherence were estimated by a method called DICS (Gross et al., 2001). In the second experiment, diffusion magnetic resonance imaging (MRI) data were collected, and major white-matter tracts were reconstructed by probabilistic tractography. Then, the individual differences in fractional anisotropy (FA) of each tract and the peak alpha frequency (PAF) were compared. In the first experiment, alpha power in IPL as well as alpha coherence between IPL and IT were significantly increased during illusory jitter perception, suggesting the involvement of communication between the dorsal and ventral visual areas in illusory jitter. In the second experiment, the PAF was found to be significantly correlated with the FA in the left vertical occipital fasciculus (Yeatman et al., 2014), connecting dorsal and ventral visual areas. Correlations with other fibers were not significant. These results consistently indicate that the communication between the dorsal and ventral visual areas, which is highlighted by the MISC, is mediated by intrinsic alpha oscillations.

56.3025 Lingering effects of response inhibition: Evidence for both control settings and memory association mechanisms Rachel Wynn[1](rwynn@gwmail.gwu.edu), Dwight Kravitz[1], Stephen Mitroff[1]; [1]The George Washington University

It is well known that response inhibition (withholding a planned or initiated response) slows subsequent responses, but the exact mechanisms of this effect are not clear. Post-inhibition slowing can have real impacts on performance, so it is important to understand the cause(s). Currently, there are two hypothesized mechanisms: adjustments in general control settings and memory associations made between the inhibition and the stimulus. To examine these possibilities, we tested the time course of inhibition effects on visual search as the two mechanisms predict different patterns; a control adjustment predicts a short-lived, general effect while a memory association predicts a lasting, stimulus-specific effect. Data were obtained from the mobile app Airport Scanner (Kedlin Co., www.airportscannergame.com), a game in which players search simulated x-ray bags for prohibited items. On < 3% of trials, the passenger is an "Air Marshal" and therefore allowed to have a prohibited item, and players must withhold their response. This app offers a massive dataset (currently >2.8 billion trials), providing sufficient data to examine rare inhibition events and their aftereffects as far as 20 trials later. We assessed performance on search trials following either an Air Marshal trial (i.e., inhibition anchor) or a search trial (i.e., search anchor). To differentiate between control setting and memory association accounts of inhibition, we compared stimulus switches, wherein the inhibition anchor and the trial of interest (lags 1-20) had different targets, and stimulus repetitions, wherein the inhibition anchor and the trial of interest had the same target. A brief negative effect was of inhibition on performance was observed during stimulus switches, consistent with adjustments in control settings. A prolonged negative effect was observed during stimulus repetitions, consistent with a memory association account. The results suggest that both memory associations and control settings influence behavior following response inhibition, but on distinct time scales.

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56.3026 Electrophysiological Correlates of Individual Differences in Visual Search Lauren Williams[1](lauren.h.williams@utah.edu), Trafton Drew[1]; [1]University of Utah

Which ERP components predict success in visual search? Despite decades of groundbreaking ERP studies in visual search, little is known about the electrophysiological correlates that predict individual differences in search performance. The aim of the current study was to determine which ERP components differentiate the best performing searchers. Participants (n=38) searched for grayscale real world objects in a lateralized circular display. The search array consisted of two, four, or six objects positioned on each side of the fixation cross. On each trial, a novel target was presented for 500 ms followed by an 800-1000 ms cue that indicated which side of the display to search for the object. The search array was presented until the participant indicated if the target was present or absent. The data was divided into the fastest and slowest searchers using a median split of response time. ERP waveforms were time-locked to the onset of the search array. No differences were found in early sensory components. The earliest component that differentiated the two groups was the n2pc, which is thought to reflect the deployment of attention (Woodman & Luck, 1999). In addition, contralateral delay activity (CDA) was greater in amplitude for the high performing group. Contrary to prior research using consistent targets across trials (Clark, et al., 2015; Luria & Vogel, 2011), these results indicate that greater reliance on WM during search predicts faster response times. Together, these results suggest that individual differences in search performance for a target that changes on each trial can largely be attributed to differences in attentional deployment and reliance on WM. Thus, it appears that the predictability of target identity may be an important factor in determining which individuals will excel at a given search task.

56.3027 **Combining individual estimates to maximize detection performance** Jennifer Corbett[1](jennifer.e.corbett@gmail.com), Aaron Clarke[1], Jaap Munneke[1]; [1]Bilkent University, Aysel Sabuncu Brain Research Center

Extending ideas abstracted from the visual systems' ability to efficiently summarize and compress information, we investigated how pairing estimates from individual observers based on their patterns of performance across the visual field can optimize performance in real world detection tasks. Observers completed several detection tasks in which they were presented with very brief (500 ms) images of 9 objects and asked to indicate the extent to which they thought each image should be "called back" for further inspection based on its likelihood of containing a pre-specified target. Strategically pairing observers based on their patterns of performance in detection tasks involving targets defined by spatial frequency, contrast, orientation, and/or size, then averaging estimates from the resultant pairs on an otherwise identical task where they had to detect the presence of a tool among other objects resulted in marked improvements in detection performance (d') over estimates taken from individual observers (all ps < .001), especially in a rare target condition where the tool target was only present on 5% of trials. Results suggest promising new methods of efficiently combining independent estimates to maximize detection performance within limited pools of observers, such as experts who must monitor images for important targets like weapons in baggage scans.

Eye Movements: Models and neural mechanisms

Tuesday, May 23, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

56.3028 **State-equation learning model for saccade adaptation** Carlos Cassanello[1,2](carlos.cassanello@bccn-berlin.de), Florian Ostendorf[3], Martin Rolfs[1,2]; [1]Bernstein Center for Computational Neuroscience Berlin, Germany, [2]Department of Psychology, Humboldt Universität zu Berlin, Germany, [3]Department of Neurology, Charité –Universitätmedizin Berlin, Germany

We present a theoretical assessment of a modified delta-rule based state-equation learning model intended to describe the temporal dynamics of saccade adaptation. By integrating the state equation we derive and predict functional phenomenological parameterizations that proved accurate in describing the evolution of saccade gain observed in a range of saccadic adaptation paradigms. We stress and study in detail the case of sinusoidal saccade adaptation. The introduction of richer dynamics through the trial-by-trial sine varying dependence of the disturbance avails two extra phenomenological parameters compared to those available in traditional fixed-step paradigms, namely the amplitude of the characteristic periodic component that the oculomotor response develops and the lag of this response with respect to the stimulus (Cassanello et al., J Neurophysiol, 2016). We derived the functional dependence that those phenomenological parameters should bear on the learning rates of the underlying state-equation model. We show that solving by iteration a state-equation that corrects for the last experienced error only, the response adopts the form of a convolution of the stimulus with weights that depend on the learning parameters. The relation between the learning parameters of the state-equation and the lag and amplitude of the periodic part of the oculomotor response can be obtained independently of explicitly finding the weights entering the convolution of the stimulus. Testing whether that predicted relationship holds gives an assessment of whether a single error-correcting channel suffices to explain the data, and ultimately sheds light on the quality of the learning model as a whole. We discuss generalizations of this approach as well as possible improvements in the experimental paradigms employed to understand saccadic adaptation.

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56.3029 **Saccadic Flow: An image independent baseline** Alasdair Clarke[1](a.clarke@essex.ac.uk), Matt Stainer[2], Ben Tatler[2], Amelia Hunt[2]; [1]Deptartment of Psychology, University of Essex, [2]School of Psychology, University of Aberdeen

The distributions of saccades and fixations during natural scene viewing are influenced by image independent biases [Tatler & Vincent 2008, J. Eye Movement Research]. One example is the central bias [Clarke & Tatler 2014, Vis. Res.], which accounts for a substantial component of fixation placement when viewing static images. We introduce the concept of saccadic flow, a generalisation of the central bias that describes the image-independent conditional probability of making a saccade to (xi+1, yi+1), given a fixation at (xi, yi). This allows us to capture the distribution of saccadic amplitudes, directions, along with fixation distributions. The model is fitted to data from eight previously published datasets of eye movements and takes the form of a multivariate Gaussian distribution of saccade landing positions (xi+1, yi+1), for a fixed starting position, (xi, yi). The parameters of the Gaussian distribution are taken to be polynomial functions of (xi, yi) and are modelled using robust regression. We then compute the likelihood of different datasets (the eight training sets, along with five previously help out test sets), and compare to the likelihood of the data given the central bias and a uniform baseline. In all cases, saccadic flow offers a large improvement over the two other baselines. We suggest that saccadic flow can be used as a useful prior when carrying out analysis of fixation locations, and can be used as a sub-module in models of eye movements during scene viewing. We demonstrate the utility of this idea by presenting bias-weighted gaze landscapes, and show that there is a link between the likelihood of a saccade under the flow model, and the salience of the following fixation.

56.3030 **Analytic eye movement patterns in face recognition are associated with enhanced face recognition performance and top-down control of visual attention** Cynthia Chan[1](cyhcynthia@gmail.com), J.J. Wong[1], Antoni Chan[2], Tatia Lee[3], Janet Hsiao[1]; [1]Department of Psychology, The University of Hong Kong, [2]Department of Computer Science, City University of Hong Kong, [3]Laboratory of Neuropsychology, The University of Hong Kong

Recent research has identified two common eye movement patterns during face perception: holistic and analytic. People using holistic patterns fixate mainly around the face center, whilst those using analytic patterns look at individual facial features in addition to the face center and exhibit more frequent gaze transitions. Analytic patterns yield better face recognition performance than holistic patterns. However, it remained unclear whether these two gaze patterns are associated with different cognitive and neural mechanisms in face processing. The present study investigated the neural correlates of these two patterns through functional magnetic resonance imaging (fMRI). Participants performed face recognition memory tasks with eye tracking and brain imaging. In addition, they performed three cognitive tests, including planning, verbal and spatial working memory tests. Eye movements were analyzed with a hidden Markov model based approach (Chuk, Chan, & Hsiao, 2014). We trained one model per participant and clustered the individual models into two patterns according to their similarities. For each individual model, the likelihood of being identified as each pattern was computed. The holistic/analytic likelihoods were correlated with the blood-oxygen-level-dependent fMRI response at the whole brain level. Consistent with previous studies, our results showed that analytic patterns were associated with better recognition performance. More importantly, a more holistic pattern was associated with more activation in perceptual regions including the inferior occipital gyrus and lateral fusiform gyrus. In contrast, a more analytic pattern exhibited more activation in areas important for top-down control of visual attention, including the frontal eye field and intraparietal sulcus. In addition, participants who adopted a more analytic pattern had better spatial working memory. These results suggest that analytic patterns are associated with better spatial working memory and recognition performance, and this advantage may be a consequence of more engagement of top-down control of visual attention.

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56.3031 **Differential responses of neurons in the macaque Lateral Intraparietal area to voluntary and reflexive saccades** Jan Churan[1](jan.churan@physik.uni-marburg.de), Stefan Dowiasch[1], Andre Kaminiarz[1], Frank Bremmer[1]; [1]Neurophysics Department, Marburg University

The macaque lateral intraparietal area (LIP) is known for its involvement in processing of saccadic eye movements (Barash et al. 1991) as well as higher cognitive concepts like attention (Bisley & Goldberg 2003), value (Sugrue et al. 2004) and numerosity (Roitman 2007). While its contribution to cognitive processes is being heavily investigated, some of its basic visuo-motor functions are not described yet. We investigated the responses of 96 single neurons from area LIP of one macaque monkey to different types of fast eye movements. The neurons were first tested using regular visually guided saccade and delayed saccade paradigms. Neurons that have shown a significant ($p < 0.05$) peri-saccadic response were further investigated using two other categories of fast eye movements. The first category were saccades interacting with smooth pursuit eye movements (SPEM) such as visually guided saccades to moving targets and catch-up saccades that are used to re-foveate a moving target during SPEM. The second category of eye movements were fast phases of the optokinetic nystagmus (OKN). We found huge differences between the responses to the two categories. While saccades in combination with SPEM revealed similar motor responses like regular visually guided saccades (significant visuo-motor responses were preserved in all neurons), none of the neurons responded significantly during the fast phases of the OKN. However, we found a modulation of activity in OKN that consisted of a significant post-saccadic inhibition in ~50% of the investigated neurons. The inhibition was regularly followed by a brief peak in activity which may be caused by a release from inhibition. We conclude that area LIP is not primarily concerned with generation of motor commands for fast eye movements but with goal directed interaction and target selection in the visual environment (Thomas & Pare 2007).

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56.3032 A model explaining visual spatial (mis-)localization of flashed stimuli in man and monkey

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How do primates localize flashed stimuli and why do eye-movements induce characteristic visual spatial mislocalization? Although of ultimate importance to everyday life, the answer to this question is still open. Physiological, behavioral and theoretical studies have suggested various neural mechanisms, from displacement of visual receptive fields during eye-movements to erroneously decoded eye-position. Here we propose a simple model for (mis-)localization during fixation and smooth pursuit eye-movements. Model predictions were verified in localization tasks in both human subjects and non-human primates. Our model assumes that localization is accomplished by a combination of two independent neural signals: a normally distributed position estimate, which is combined with an (erroneous) eye-position representation. To test our model, we employed localization of briefly presented stimuli during monocular fixation and smooth pursuit eye-movements in both, humans and monkeys. Human subjects reported perceived location by an established procedure (ruler), while monkeys indicated their percept by means of a saccade. Importantly, monocular viewing is challenged by a gap in retinal space, i.e. the blind spot. In contrast, our model predicts a gap-free, quasi continuous perceptual space with perceived locations covering also the area of the blind spot. According to our model, perceived space is shifted in the direction of smooth pursuit, as previously reported also for binocular eye-movements. Our experiments confirmed both model predictions in man and monkey. First, all subjects showed a continuous perceptual space with no obvious gap at the blind spot. Second, smooth pursuit induced an overall shift of the perceptual map with respect to fixation. Our findings imply a combination of two independent neural signals as the neural basis of flash localization: a visual map and an eye-position signal. Our model agrees well with previous studies suggesting the source of perceptual mislocalization during eye-movements to be an erroneous internal representation of eye-position.

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56.3033 DeepGaze II: Predicting fixations from deep features over time and tasks

Matthias Kümmerer[1](matthias.kuemmerer@bethgelab.org), Tom Wallis[1,2], Matthias Bethge[1,2,3]; [1]Werner-Reichardt-Centre for Integrative Neuroscience, University Tübingen, [2]Bernstein Center for Computational Neuroscience, Tübingen, [3]Max-Planck Institute for Biological Cybernetics, Tübingen

Where humans choose to look can tell us a lot about behaviour in a variety of tasks. Over the last decade numerous models have been proposed to explain fixations when viewing still images. Until recently these models failed to capture a substantial amount of the explainable mutual information between image content and the fixation locations (Kümmerer et al, PNAS 2015). This limitation can be tackled effectively by using a transfer learning strategy ("DeepGaze I", Kümmerer et al. ICLR workshop 2015), in which features learned on object recognition are used to predict fixations. Our new model "DeepGaze II" converts an image into the high-dimensional feature space of the VGG network. A simple readout network is then used to yield a density prediction. The readout network is pre-trained on the SALICON dataset and fine-tuned on the MIT1003 dataset. DeepGaze II explains 82% of the explainable information on held out data and is achieving top performance on the MIT Saliency Benchmark. The modular architecture of DeepGaze II allows a number of interesting applications. By retraining on partial data, we show that fixations after 500ms presentation time are driven by qualitatively different features than the first 500ms, and we can predict on which images these changes will be largest. Additionally we analyse how different viewing tasks (dataset from Koehler et al. 2014) change fixation behaviour and show that we are able to predict the viewing task from the fixation locations. Finally, we investigate how much fixations are driven by low-level cues versus high-level content: By replacing the VGG features with isotropic mean-luminance-contrast features, we create a low-level saliency model that outperforms all saliency models before DeepGaze I (including saliency models using DNNs and other high level features). We analyse how the contributions of high-level and low-level features to fixation locations change over time.

Acknowledgement: German Research Foundation (DFG priority program 1527, Sachbeihilfe BE 3848/2-1)

56.3034 Visual-motor response fields and spatial tuning in supplementary eye field (SEF) of the head unrestrained monkeys.

Harbandhan Arora[1,2,3,4](harbandhan.arora@gmail.com), Vishal Bharmauria[1,2], Amirsaman Sajad[1,2,3,4,5], Xiaogang Yan[1,2,3], Hongying Wang[1,2,3], John Crawford[1-6]; [1]York Center for Vision Research, [2]Vision: Science to applications program, [3]Canadian action and perception network, [4]Department of Biology, York university,Toronto,ON,Canada M3J 1P3, [5]York Neuroscience Graduate Diploma Program, [6]Department of psychology and kinesiology, York University,Toronto,ON,

We recently used an analytic technique involving statistical fits of different spatial models against neural response fields to show that visual response encodes target direction and motor response encodes planned gaze direction (both relative to initial eye orientation) in the superior colliculus (SC; Sadeh et al. European journal of Neuroscience.2015) and in the frontal eye fields (FEF; Sajad et al. Cerebral Cortex.2015). Here, we applied a similar methodology to investigate if similar spatial codes are employed in the supplementary eye field (SEF). Since the SEF and FEF have strong reciprocal connections, we hypothesized that they would show similar egocentric spatial codes. Monkeys were trained to make gaze shifts toward briefly presented targets distributed throughout the potential neuronal receptive fields. After a variable memory delay, a go signal was provided for a gaze saccade. Experiments were performed in head-unrestrained conditions with 3-D eye and head recordings to allow discrimination of all egocentric models of gaze coding. Until now, approximately 60 neurons in monkey have been recorded in relation to the above task, 20 with visual responses, 17 with motor responses, and 5 Visuomotor. These have been analyzed employing our previous methodology, including the use of non-parametric fits to response fields. Preliminary data show that both the visual and motor response fields of most SEF neurons show broad receptive fields with poorly defined spatial tuning, and considerable variability in activity for each target direction unrelated to any measured spatial parameter. To date (unlike the FEF), SEF visual population shows a slight (non-significant) bias toward a target within space (Ts) spatial model, but only one model (target relative to head) was statistically eliminated. These preliminary data suggest that the SEF plays a minor role in specifying the spatial direction of targets and gaze plans compared with the SC and FEF.

See page 3 for Abstract Numbering System

56.3035 **Processing of imminent collision information in human SC and Pulvinar** Jinyou Zou[1](jjzou_6@163.com), Sheng He[1,2], Peng Zhang[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, Beijing 100101, China, [2]Department of Psychology, University of Minnesota, Minneapolis, MN 55455

Detecting imminent collision is essential for survival. Recent studies revealed subcortical circuits responding to looming stimulus in rodents. Little is known about how human subcortical visual pathways process collision information. Using fMRI, we studied how the superior colliculus (SC) and pulvinar of thalamus respond to potential collision information. Visual stimuli depicting an incoming ball towards the subject were presented with 3D LED monitors. The incoming ball appeared in one of the four quadrants of visual field. Within each quadrant, the trajectory of incoming ball varied slightly to either hit the center of face, hit the eye, near-miss or miss the head of observers. subjects responded whether the ball was on a collision course with their head or not. Behavioral results show that subjects performed slightly better detecting collision (hit vs. miss) for stimuli in the upper visual field than in the lower visual field. FMRI data showed that the superficial layers of the SC were sensitive to the looming information from the contralateral visual field, especially when the looming object came from the upper visual field and was on a collision course leading to a direct hit at the center of the subject head. A sub-region in the ventral Pulvinar was also sensitive to the incoming object on a collision course from the contralateral side, showing the strongest response when the incoming object would hit the subjects' contralateral eye (on the same side of the incoming object). These results suggest that human SC and Pulvinar are closely involved in processing incoming objects potentially on a collision course.

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56.3036 **MICROCIRCUITRY OF VISUAL PERFORMANCE MONITORING** Amirsaman Sajad[1](amirsaman.sajad@vanderbilt.edu), Jeffrey Schall[1]; [1]Department of Psychology, Vanderbilt Vision Research Center, Center for Integrative & Cognitive Neuroscience, Vanderbilt University

Being error prone, the context and consequences of visual behavior must be monitored to achieve goals. Previous work in macaque monkeys performing a saccade countermanding task has found that neural spiking and field potential signals occur in the supplementary eye field (SEF) and anterior cingulate cortex when errors are made, when reward is expected and when conflict between competing saccade plans arises. We will now report the laminar organization of these visual performance monitoring signals in neurophysiological data collected with linear electrode arrays (U-probe) sampling all layers of the SEF. We isolated 293 cells in 16 penetrations from two monkeys. Of these, 273 were modulated in the period between target and 200 ms after reinforcement. Of the 273, 238 had at least one of 5 signal types: visual (32%), motor (52%), error (34%), reinforcement (63%), and conflict (18%) with the majority multiplexed. We have found that neurons with particular signals are concentrated in specific layers. Neurons signaling saccade plan conflict are concentrated in upper layers (Fisher exact test, $p = 0.025$). Similarly, the incidence of error (Fisher $p = 0.030$), reward (Fisher $p = 0.010$) and visual (Fisher $p < 0.001$) neurons varied across layers, but perisaccadic (Fisher $p = 0.600$) neurons did not. We have also discovered reproducibility of discharge profiles across repeated penetrations but pronounced variability in penetrations at different locations in different monkeys. These findings contribute to the evaluation of alternative hypotheses about medial frontal function, to understanding the contributions of laminar-specific cortical/subcortical and feedforward/ feedback processes, to constraining circuit-level models of executive control and to guiding forward and inverse modeling solutions of the ERN. (We thank D. Godlove for sharing data)

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56.3037 **Dissociable effects of saccades on hippocampal local field potential power and phase** Julio Martinez-Trujillo[1](julio.martinez@mcgill.ca), Roberto Gulli[1,2], Guillaume Doucet[1,3], Benjamin Corrigan[1,2]; [1]Centre for Brain and Mind and Robarts Research Institute, Western University, Ontario, Canada , [2]Integrative Program in Neuroscience, McGill University, Quebec, Canada, [3]Department of Physiology, McGill University, Quebec, Canada

Saccadic eye movements to reorient gaze are critical to efficient scene exploration in primates. During saccades, neural activity in visually responsive areas is suppressed, leading to widespread perturbation in local field potentials (LFPs) known as phase resetting. Saccade-aligned phase resetting has been observed in primate hippocampal LFPs (4-12 Hz) during visual scene exploration, and analogously aligned to object sniffing in rodents completing an associative learning task. To disambiguate motor-activity related changes and object-sampling related changes in primate LFPs during 2D and 3D exploration, we trained two monkeys to complete three tasks while we recorded eye movements and hippocampal LFPs. In a visually guided saccade task (VGS), monkeys were rewarded for making saccades to small white dots on a gray screen. The remaining two tasks required free navigation in a novel virtual reality environment using a joystick. In the virtual foraging task, animals searched for, and navigated to, a red volume which was randomly relocated within the environment. In the virtual associative memory task, monkeys learned a reversed two-context, three-object reward value hierarchy. Eye movements and intra-hippocampal LFPs were simultaneously recorded in each task in a total of 93 channels over 41 sessions. In all tasks, saccade-aligned phase resetting was observed between 4-16 Hz 80-100 ms after saccade onset. Interestingly, the consistency of saccade aligned phase resetting was lowest during VGS in the 8-12 Hz range, and under no circumstances correlated with saccade amplitude. Conversely, gamma range (~64-111Hz) power was elevated ~20ms around the saccade onset in all tasks, and gamma power correlated positively with saccade amplitude across all tasks. These results illustrate dissociable and frequency specific signatures of saccade features on hippocampal LFP power and phase. Phase resetting may be critical for coordination of hippocampal networks during visual exploration of simple scenes and navigable environments.

Acknowledgement: CIHR, NSERC

56.3038 **Brain responses elicited by saccadic fixations on natural images of faces** Yingxin Jia[1](yingxin.jia10@gmail.com), Christopher Tyler[1]; [1]Smith-Kettlewell Eye Research Institute, San Francisco, CA

Introduction. In most previous electroencephalography (EEG) experiments, visual processing is examined with large eye movements precluded, making it difficult to determine the cortical mechanisms involved in the control of eye movements. A previous study (Jia & Tyler, 2016) validated the capability of simultaneous EEG and eye movement measurements with electrooculography (EOG) signals. The current study co-registered the EEG and EOG signals to reveal neural correlates of natural image processing while making fixational eye movements across images of faces. Methods. The fixation targets consisted of 18 white circles appearing in a window (29° by 22°) filled with a) a blank field, b) a white noise pattern, c) a natural image of a face, or d) only the facial features within the target circles with a noise pattern outside them. The targets were each presented for 2s in random order. Participants were required to saccade onto the presented stimulus and maintain fixation until the next stimulus appeared. EEG and EOG were measured simultaneously with a high-density EGI electrode net at a 500 Hz sampling rate. The resultant EEG signals were pre-processed and analyzed by Principal Component Analysis (PCA) to reveal visual fixation- and saccade-related potentials. Results. The analysis revealed a primary EOG eye movement component with a saccade-like waveform derived from the facial area around eyes. A slow anticipatory component was seen before the saccades. A transient Frontal Eye Field component accompanied the saccades. A posterior component with a single negative peak was found around the time of the saccade, interpretable as representing the neural substrate for saccadic suppression. Occipital components peaking 100-200 ms after the saccade were interpretable as the cortical responses to the targets. Conclusion. These findings show that local feature viewing of facial images elicits a range of saccadic control and visual cortical response components.

Acknowledgement: Rachel C. Atkinson fellowship

56.3039 Oculomotor assessment of diurnal arousal variations Jeffrey Mulligan[1](jeffrey.b.mulligan@nasa.gov), Carolina Diaz-Piedra[2], Leandro Di Stasi[3]; [1]Human Systems Integration division, NASA Ames Research Center, USA, [2]Mind, Brain, and Behavior Research Center, University of Granada, Spain, [3]Department of General Psychology, University of Padova, Italy

Saccadic and pupil responses are reliable indices of arousal decrement (e.g. fatigue), that might be exploited to improve work schedule guidelines. In this study, we tested the sensitivity of a short 30-s oculomotor test to detect diurnal arousal variations. Twelve participants (5 females, 7 males, 37.7±11.9 years) volunteered to be assessed every hour (66±20 min) for three consecutive working days, during their regular office-hours. We used a fully automated testing system, the FIT 2000 Fitness Impairment Tester (Pulse Medical Instruments Inc., Rockville, MD, USA), to measure and record saccadic peak velocity, pupil diameter, and latency and amplitude of the pupillary light reflex. In addition, we collected subjective levels of arousal using the Stanford Sleepiness Scale, and body core temperature. We analyzed the data using a linear mixed model approach for longitudinal data. Both saccadic velocity and subjective alertness decreased over the course of a day, while body core temperature increased (all p-values $< .05$). The data also weakly suggested an increase of the pupil diameter ($p=.07$). The findings support the use of oculomotor indices in the assessment of arousal and fatigue in applied settings.

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EYE MOVEMENTS: PERCEPTION

Tuesday, May 23, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

56.3040 Learning when to blink: Environmental statistics guide blinking behavior. David Hoppe[1](hoppe@psychologie.tu-darmstadt.de), Stefan Helfmann[1], Constantin Rothkopf[1,2,3]; [1]Technical University Darmstadt, Department of Psychology, Darmstadt, Germany, [2]Technical University Darmstadt, Cognitive Science Centre, Darmstadt, Germany, [3]Frankfurt Institute for Advanced Studies, Goethe University, Frankfurt, Germany

Our eyes blink 15 – 17 times per minute and during this time the stream of visual information is interrupted for 100-400 ms leading to perceptual gaps every two to three seconds. There are numerous situations in which these gaps can lead to negative outcomes including motor control, fight and flight scenarios, and social interactions. Hence, choosing carefully when to blink should be advantageous compared to blinking at random. Various studies indicate a connection between the current behavioral situation and blinking. Blinking rates have been found to decrease during reading but to increase during conversations and when fatigued. Further, blinking behavior is influenced by task difficulty and whether the visual input is meaningful to a person. While there exists a lot of empirical work pointing to the connection between blinking and the visual environment, the environmental regularities are usually complex and unknown. We present a controlled blinking experiment with parametrically generated environmental statistics. In our study, subjects directed their gaze to a grey dot moving on a circular trajectory (100 laps per block) in order to detect events (50 ms in duration). Hence, a normal blink could lead to missing an event. By probabilistically drawing events from spatial probability distributions we could investigate the relationship between event-statistics and blinks. Our results show a clear connection between blinking rates and environmental statistics. Subjects were able to learn regularities in the event generating process and as a consequence adapted their behavior. In addition to the behavioral results we investigated the blinking process by developing a computational model. We show that uncertainty about the statistics as well as costs for blink suppression are sufficient to reproduce key characteristics of the blinking behavior. Remarkably, our computational model predicts various aspects of the visual behavior such as the distribution of time intervals between blinking.

56.3041 Fusion breaks at extreme eye positions due to lack of adaptation in the vergence system Elizabeth Fast[1](fastx055@umn.edu), Linus Holm[2], Linda McLoon[3], Stephen Engel[1]; [1]University of Minnesota, Department of Psychology, [2]Umeå University, Department of Psychology, [3]University of Minnesota, Department of Ophthalmology and Visual Neurosciences

What limits our ability to diverge or converge our eyes? Current models suggest that vergence depends upon a slow, adaptable tonic component that determines the "baseline" position of our eyes, and a fast fusional component activated primarily by retinal disparity, which drives additional vergence. This framework predicts that as images require larger vergence movements to stay binocularly fused, putting the eyes in relatively extreme positions, fusion should break only if adaptation cannot maintain high enough baselines. We tested this prediction by adapting the vergence systems of 8 subjects to sequential increases of 2° image disparity, which produced divergent eye movements. Beginning at 3°, subjects adapted for 5 min blocks, before disparity increased further, to a maximum of 15°. Subjects viewed an image of an outdoor scene, while relative eye position was measured with an eye tracker and a behavioral measure. To estimate adaptation of the baseline component we measured phoria, the misalignment of the two eyes with no disparity present. Phoria should be small when adaptation is complete, and was measured every 30 s by replacing the image in one eye with a gray field for 10 s. Results showed evidence of vergence adaptation; phorias decreased on average within a block by 1.27° degrees. However, both eyetracking and behavioral estimates of adaptation became smaller across successive blocks ($p < 0.01$). One interpretation of these results is that adaptation became less complete as eye alignment became more extreme. Without complete adaptation of the tonic baseline, disparity became too large for the fast fusional component to overcome, and fusion broke. These results predict that longer viewing times could produce more complete adaptation, and allow vergence to reach previously unattainable positions, potentially beneficial for the treatment of strabismus.

Acknowledgement: Torske Klubben Fellowship

56.3042 Gaze-in-World movement Classification for Unconstrained Head Motion during Natural Tasks. Rakshit Kothari[1](rsk3900@rit.edu), Kamran Binaee[1], Reynold Bailey[2], Christopher Kanan[1], Gabriel Diaz[1], Jeff Pelz[1]; [1]Chester F. Carlson Center for Imaging Sciences, RIT, [2]B. Thomas Golisano College of Computing and Information Sciences, RIT

Accurate classification of eye movements is an integral component of many psychophysical experiments. Most event classifiers are restricted to the analysis of eye-in-head (EIHv) vectors while the head is fixed, and detect two classes of gaze events, namely fixations and saccades. Classification of eye movements as Vestibular Ocular reflex (VOR) or Smooth pursuits (SP) require that we compensate gaze motion with a person's head movements. As the complexity of naturalistic behavioral paradigms increases, so does the need for gaze classification with head-free motion which could detect these complex eye movements. We propose the use of a supervised Machine Learning (ML) classifier for the automated analysis of head free gaze signal. As a preliminary test, we used a SVM classifier to label a 60 Hz test dataset from a virtual reality ball catching task into periods of fixations, saccades and pursuit. This preliminary test resulted in 94% accuracy in a sample to sample comparison with an artificially generated set of gaze movements reflective of measured gaze statistics, and visual inspection shows very high correspondence to subjective analysis of the gaze signal. This promising methodology has since been extended to the analysis of data collected during natural tasks. Five subjects' head and gaze movements were recorded using an IMU and a 120 Hz SMI Wireless ETG2 as they performed four different natural tasks for 10 minutes each. This yielded 120 minutes of angular velocity data of the gaze in world vector (GIWv) during natural tasks. Four experts manually annotated a subset of the data as periods of fixation, saccade, smooth pursuit, and blinks. Inter-labeler reliability was measured to generate a confidence metric and a cost function for misclassifications. We summarize the statistics of natural eye movements and compare various ML based temporal series classification schemes.

56.3043 Enhancing discrimination of fine spatial details with fixational eye movements: Is there an extra-retinal component? Mehmet Agaoglu[1](mna@berkeley.edu), Christy Sheehy[1], Pavan Tiruveedhula[1], Austin Roorda[1], Susana Chung[1]; [1]School of Optometry, University of California, Berkeley

Fixational eye movements (FEMs) have been known to prevent visual fading. Recent work showed that when FEMs are compensated for by stabilizing visual stimuli on the retina, orientation discrimination of high-spatial frequency gratings is significantly impaired. Here, we tested the hypothesis that FEMs are optimally tuned for discrimination of fine spatial details at the fovea. We asked five observers to report the orientation (±45°) of a 12cpd grating. We used a state-of-the-art Tracking Scanning Laser Ophthalmoscope to deliver the stimuli. By using a range of stabilization gains, i.e., how much of FEMs is compensated for, we obtained a wide range of retinal motion across trials. Note that in contrast to the trials where stimulus position was modulated (gain≠0), there was no stimulus motion on the display in the unstabilized trials (gain=0). We extracted eye and stimulus positions from recorded videos using a cross-correlation method, and sorted trials based on the area enclosed by the 68% isoline (ISOA) of the distribution of retinal positions of the grating. Consistent with previous reports, we found that performance in the unstabilized trials was significantly higher than the minimum performance in the stimulus-modulated trials with smaller ISOAs (less retinal motion) [84±2% vs 75±2% correct]. However, contrary to the optimal tuning hypothesis, performance in the stimulus-modulated trials increased, and for some observers, showed non-monotonic changes with decreasing ISOAs. The comparison of performance at the smallest ISOAs and the unstabilized performance yielded no significant difference. Rather surprisingly, performance in a set of stimulus-modulated trials with comparable retinal motion (mean ISOA) as the unstabilized trials [74±3%] was significantly lower than the unstabilized performance, suggesting that retinal motion due to FEMs is not the sole reason of performance enhancement. When retinal motion and eye movements are fully matched, performance deteriorates suggesting involvement of an extra-retinal process.

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56.3044 Measuring degraded visual sensitivity using microsaccades Chris Scholes[1](chris.scholes@nottingham.ac.uk), Jonathan Denniss[1], Paul McGraw[1], Neil Roach[1]; [1]School of Psychology, University of Nottingham

We previously demonstrated that contrast sensitivity can be accurately predicted from changes in the rate at which normal individuals make microsaccades: small, involuntary fixational eye movements (Scholes et al. 2015, Proc. R. Soc. B 282: 20151568). Here, we expand this previous work to include two groups of individuals with visual sensitivity loss that has either an optical (cataract) or neural (amblyopia) origin. Contrast sensitivity functions were first measured psychophysically and used to inform the choice of stimulus parameters for the main experiment. The highest spatial frequency for which each subject could reliably detect a 75% contrast Gabor was selected and contrast levels were adjusted to span threshold. For the majority of trials, subjects were required to fixate a central dot as Gabor stimuli were passively presented. However, on a subset of trials (indicated by a tone) subjects were required to discriminate the orientation of the Gabor (±45 degrees), allowing us to collect a concurrent behavioural estimate of contrast sensitivity. Eye movements were recorded using an Eyelink 1000 and microsaccades were detected using a velocity-based algorithm. Each subject completed 400 passive trials per contrast and microsaccade rates were established in an epoch around stimulus presentation. Microsaccade rate modulations were characterized by computing the absolute difference between an individual's base microsaccade rate and the modulated rate for a particular contrast. Oculomotor thresholds, calculated from logistic fits to this measure, corresponded closely to behavioural thresholds, capturing the variability in absolute thresholds (11 – 64%) at a range of spatial frequencies (1-12 cpd) across 30 subjects. Our data indicate that visual sensitivity can be accurately predicted using fixational eye movements both for a range of stimulus conditions and in individuals with sensitivity losses with both optical and neural origins.

Acknowledgement: Medical Research Council

56.3045 The role of small eye movements in spatial exploration Natalya Shelchkova[1](nshelch@hotmail.com), Christie Tang[1], Michele Rucci[1], Martina Poletti[1]; [1]Department of Psychological and Brain Sciences, College of Arts and Sciences, Boston University

Spatial exploration occurs at multiple scales. At the relatively large scale at which it is commonly investigated, humans use saccades to explore a scene and examine objects of interest by means of the high-acuity foveola. Yet, many everyday tasks require exploration at a finer scale, as objects are often viewed from a distance and tasks that require analysis of fine details often occur. Previous research has shown that, contrary to common intuition, simply placing the attended stimulus within the foveola is not sufficient to perform well in high-acuity tasks, and that small eye movements play important roles. Here we examine the exploratory role of fixational eye movements in a common high-acuity task, the evaluation of facial expression. Human observers were asked to judge facial expressions when faces covered approximately the size of the foveola (1 deg diameter), as it normally happens when looking at a person from a distance larger than 13 meters. A high-resolution Dual Purkinje Image eyetracker was used to record eye movements and was coupled with a custom gaze-contingent calibration procedure that has been shown to improve gaze localization by approximately one order of magnitude over standard methods. We show that spatial exploration of foveal stimuli follows strategies very similar to those used to explore broader scenes. Visual exploration is primarily executed by means of precisely controlled microsaccades (average amplitude: 14 arcmin), which center gaze on salient and task-relevant regions. Both bottom-up and top-down factors influence the pattern of microsaccades; in the presence of the same visual stimulation exploration changes based on the demands of the task. These results indicate that observers do not simply fixate on foveated stimuli, but actively explore them. This level of oculomotor control is necessary to operate effectively in tasks that require high-acuity vision and implies the existence of high-resolution saliency maps.

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56.3046 Saccadic eye movements affect perceived speed Alexander Goettker[1](Alexander.Goettker@psychol.uni-giessen.de), Doris Braun[1], Alexander Schütz[1,2], Karl Gegenfurtner[1]; [1]Justus-Liebig-University Gießen, Germany, [2]Philipps-Universität Marburg, Germany

Smooth pursuit and saccadic eye movements are used in combination to track moving targets. Pursuit is mainly driven by the velocity of the target and saccades by its position, even though interactions between these input signals have been shown. We wanted to see whether different oculomotor responses during the tracking of a moving object lead to changes in perceived speed. In a speed discrimination task observers had to judge the speed of the pursuit target in comparison to a memorized standard stimulus. We manipulated the eye crossing time in a classical Rashbass step-ramp paradigm to elicit different eye movement responses (pure pursuit, backward saccades, forward saccades) to targets moving at the same physical speed. Both eye movements, pursuit and additional catch-up saccades, used for tracking a moving target adjusted their responses based on the position and speed of the target. The pursuit system adjusted the speed of the eye to account for the target position, but interestingly, only the occurrence and direction of additional saccadic eye movements was related to the perceptual judgments of the participants. Trials with forward saccades were perceived as faster than trials with backward saccades. We conducted an additional fixation control condition and found that the same physical targets led to smaller differences in perceived speed than trials with saccadic eye movements during tracking. Previous results have shown interactions between smooth pursuit and saccades, and interactions in the use of position and velocity in the control of these eye movements. Our results show that the execution of catch-up saccades can also affect the perceived speed of the tracked target. Saccades could be used as evidence for an update of an internal representation of target speed or the high eye speed during saccades biases the extraretinal signal used to account for induced motion during tracking.

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56.3047 Visual features of Saccadic Suppression of Displacement Rodrigo Balp[1,2](balpeaux@gmail.com), Florian Waszak[1,2], Thérèse Collins[1,2]; [1]Laboratoire Psychologie de la Perception, Université Paris Descartes, [2]Centre Nationnal de la Recherche Scientifique

The world is perceived as stable, even when the retinal positions of objects change during saccadic eye movements. The underlying mechanisms of this stability remains debated. The retinal consequences of eye movements may be cancelled out or compensated by an equal and opposite signal (efference copy), and leftover discrepancies between the retinal and efference signals may be ignored (the assumption of prior of stability). In the laboratory, stability is often probed with the saccadic suppression of displacement (SSD) paradigm, in which observers report the direction of displacement of the target, which occurs during a saccade, as the eyes are in mid-flight . Performance is notoriously bad, but can be increased by stepping the target orthogonally to saccade direction, or by inserting a ~250 ms blank between saccade onset and target displacement. These manipulations may break object constancy and allow observers to access the discrepancy between the retinal consequences of the eye movement and the location of the post-saccadic target. The current project proposes to explore whether target features alleviate SSD. We hypothesized that when visual targets undergo a feature change these will relieve saccadic suppression, in a manner comparable to the blanking effect. Preliminary results suggest that SSD decreases when Gabor stimuli undergo an orientation change, suggesting that features do indeed participate in trans-saccadic correspondence.

56.3048 **Saccadic Suppression during Voluntary vs Reactive Saccades** Svenja Gremmler[1](svenja.gremmler@uni-muenster.de), Markus Lappe[1]; [1]Department of Psychology, University of Muenster

Saccades are fast eye movements that re-orient gaze direction. While in natural conditions saccades are usually self-paced, in the laboratory saccades are often triggered by appearing targets. The generation of these "voluntary" and "reactive" saccades have been shown to involve partially different cortical pathways. However, saccades of either type confront the visual system with a major challenge since they cause fast image motion on the retina. The visual system counteracts this situation by a neural process called saccadic suppression: During the eye movement the visual sensitivity is strongly decreased. This modulation of neural response properties in the visual pathway starts about 50 ms before the saccade. Thus, an extra-retinal signal, which is generated and projected already during saccade preparation, must be involved in the process of suppression. Since saccade generation differs in voluntary and reactive saccades, timing and nature of this extra-retinal signal and its impact on visual sensitivity might differ, too. In this study, we measured detection thresholds for luminance stimuli that were flashed during the execution of voluntary and reactive saccades and during fixation. Subjects reported if they perceived a probe bar, flashed with luminance values between 0 and 27.4 mcd/m^2 during saccades and 0 and 7.1 mcd/m^2 during fixation. The detection thresholds of each subject in all three conditions was determined as the luminance value at which a psychometric data fit exceeds 50% correct positive responses. We found that the detection threshold was increased during saccade execution compared to fixation and furthermore we found stronger suppression during voluntary vs reactive saccades. This result provides further evidence for partially different networks for the saccade types. Stronger suppression in voluntary saccades could arise from a different composition of the extra-retinal signal that activates suppression or could indicate that the suppression process itself partially differs between voluntary and reactive saccades.

56.3049 **Distracting attention impairs trans-saccadic integration** Emma Stewart[1](emma.e.m.stewart@gmail.com), Alexander Schütz[1]; [1]Allgemeine und Biologische Psychologie, Philipps- Universität Marburg, Marburg, Germany

Humans usually locate objects in the peripheral field of view before using saccadic eye movements to project them on the fovea for further inspection. Therefore, low resolution pre-saccadic information has to be integrated with high resolution post-saccadic information. While humans achieve integration in a near-optimal manner, the mechanisms supporting integration are still unclear – one potential mechanism is pre-motor attention. We presented an attentional distractor during an integration task to investigate whether disrupting pre-saccadic attention impairs trans-saccadic integration. Participants were presented with randomly oriented Gabors shown in either peripheral vision before a saccade, in foveal vision after a saccade, or across the entire saccade (integration trials). An attentional distractor appeared at a variable time relative to saccade onset on each trial. Participants freely selected the perceived orientation of the presented stimulus, and performance was measured as the angular distance between actual and reported stimulus orientation. For each condition, the time-course of performance across the saccade was calculated using a moving window spanning -200 ms to +200 ms relative to saccade onset. Results showed that integration performance declined with distractors presented around 100 ms before saccade onset. Additional analyses compared measures of motor planning error (saccade curvature and saccade latency) with integration performance across the time-course of the saccade: the time at which the distractor impaired integration performance most was highly correlated with the time at which both measures of motor error were the highest. These results indicate that presenting an attentional distractor during a saccade impairs trans-saccadic integration, suggesting that attention may be a mechanism underlying this integration process. The correlation between impairment on integration and motor performance suggests that pre-motor attention may be integral in motor planning and in the maintenance of perceptual stability across a saccade.

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Perception and Action: Theory and mechanisms

Tuesday, May 23, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4001 **Fractional-Order Information for Interception** Frank Zaal[1](f.t.j.m.zaal@umcg.nl), Rémy Casanova[2], Simon Ledouit[2], Reinoud Bootsma[2]; [1]Center for Human Movement Sciences, University Medical Center Groningen, University of Groningen, The Netherlands, [2]Institut des Sciences du Mouvement, Centre National de la Recherche Scientifique, Aix-Marseille University, France

Seeking or avoiding contact with stationary and moving targets is at the heart of many day-to-day behavior in humans and other animals. A close inspection of the visual control of such behavior shows that different strategies seem to be used in different situations. For instance, when considering a lateral-interception task, in which soccer goalkeepers have to stop balls shot at their goal, and in which these balls either have a sideways curve or not, the goalkeepers seem to rely on different informational variables in both conditions. This difference could be captured by the (integer) order of the informational variable: zeroth-order information would mean a pursuit strategy and first-order information would mean an interception strategy. The present contribution proposes that both situations can be understood to originate from the use of the same, fractional-order (i.e., non-integer), informational variable, the order of which relies on the specifics of the target movement. That is to say, rather than nulling the bearing angle (zeroth order) or its speed (first order), a fractional derivative of this optical angle is being nulled by the goalkeeper. Moreover, the specific fractional order is arrived at depending on the situation: every situations asks for its own order of control. We have elaborated a first proof of concept, based on experimental data in which goalkeepers, in virtual reality, were to catch balls arriving at the goal line. The order of control was close to 1.0 and 1.8 for the trajectories without and with sidespin, respectively. In addition, the model was also able to account for the systematic patterns in movement initiation times. The current work holds great promise for arriving at a unified account of interception and avoidance.

56.4002 **Bayesian adaptive stimuli selection for dissociating psychophysical models** James Cooke[1](j.cooke@donders.ru.nl), Robert van Beers[1,2], Luc Selen[1], W.Pieter Medendorp[1]; [1]Radboud University, Donders Institute for Brain, Cognition & Behavior, Nijmegen, The Netherlands, [2]MOVE Research Institute, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands

Comparing models allows us to test different hypotheses regarding the computational basis of perception and action. One difficulty in model comparison is that it requires testing stimuli for which the models make different predictions. To date, experiments contain typically a predetermined set of stimuli or sample randomly over a large range of stimulus values. Both methods have limitations; a predetermined set may not contain the stimuli that dissociate the different models and random sampling may be inefficient. To overcome these limitations, we derived an algorithm to efficiently dissociate psychophysical models using adaptive stimuli selection. Formally, our method selects stimuli that minimize the expected entropy of the posterior distribution across models after the next stimulus or stimulus pair

Tuesday PM

has been presented. To test our algorithm, we considered the problem of comparing sensory noise models. Many computational models assume a specific perceptual noise type, like constant noise, Weber noise or a combination. The appropriate noise model can be inferred using a 2-AFC task. We simulated ideal observers with different noise models performing such a task. Stimuli were selected randomly or using our adaptive algorithm. On average the number of trials required to converge to the correct model was lower for the adaptive algorithm compared to random sampling. We also verified our algorithm in human subjects by inferring which of the aforementioned models underlie speed perception. Subjects were presented with two Gabor patches moving at different speeds and indicated which was faster. On a trial the speeds were either chosen randomly or by the adaptive algorithm. The adaptive procedure converged to the model reported in earlier work (Stocker & Simoncelli, 2006), whereas the random sampling method was often inconclusive. We conclude that our technique is more efficient and more reliable than the methods that are used to date to dissociate psychophysical models.

56.4003 **Dynamic visual localization with moving dot clouds** Shannon Locke[1](sml726@nyu.edu), Michael Landy[1,2], Pascal Mamassian[3], Eero Simoncelli[1,2,4]; [1]Dept. of Psychology, New York University, New York, [2]Center for Neural Science, New York University, New York, [3]Laboratoire des Systèmes Perceptifs, CNRS UMR 8248, Paris, France Département d'Études Cognitives, École Normale Supérieure, Paris, France, [4]Courant Institute of Mathematical Sciences, New York University, New York

Introduction: Humans and animals are often make sensory estimates in environments that are dynamic, where the feature or object of interest changes over time. This form of estimation is not well captured by traditional experiments based on binary-choice, reaction-time tasks and stimuli with fixed properties. Inspired by Bonnen et al. (2015), we explored dynamic perceptual estimation using a visuo-motor tracking task. Methods: Participants used a computer mouse to track a target, the mean of a 2D circular Gaussian distribution, as it followed a horizontal random-walk trajectory. High-contrast white dots were drawn stochastically from the distribution every 17 ms. In the main task, the mean of the distribution was not displayed and needed to be inferred from the dot cloud. A control task presented a red dot at the target location. After each 20 sec trial, points were awarded in inverse proportion to the RMSE between target and cursor positions. Model: A Bayesian ideal-observer model was constructed for this task. The estimation component was a Kalman filter that determined the ideal temporal weighting function, assuming knowledge of the true variances of the sensory information and random-walk trajectory. Plausible sensorimotor perturbations were added to the inputs/outputs of the Kalman filter, including temporal lags and additional noise. Results/Discussion: Across participants, the average estimated tracking lag was 400 ms in the main task. When this temporal lag was included in the model, we found that participants tracked the trajectory of the invisible target in a manner indistinguishable from the ideal observer. In the control task, the estimated temporal lag was 330 ms, suggesting that spatial integration and decisional factors require around 70 ms. These results demonstrate normal healthy adults are capable of optimal estimation in complex, dynamic contexts that require spatial and temporal integration as well as learning statistical information about the environment.

Acknowledgement: NSF BCS-1430262

56.4004 **Biophysically plausible neural model for the interaction between visual and motor representations of action** Mohammad Hovaidi Ardestani[1,2](Mohammad.Hovaidi-Ardestani@uni-tuebingen.de), Martin Giese[1]; [1]Section for Computational Sensomotorics, Department of Cognitive Neurology, Hertie Institute for Clinical Brain Research, and Centre for Integrative Neuroscience, University Clinic Tübingen, D-72076 Tübingen, Germany, [2]IMPRS for Cognitive and Systems Neuroscience, University of Tübingen, Germany

INTRODUCTION: Action perception and action execution are intrinsically linked in the human brain. Experiments show that concurrent motor execution influences the visual perception of actions. This interaction is mediated by action-selective neurons in premotor and parietal cortex. We have developed a model based on biophysically realistic spiking neurons that accounts for such interactions. METHODS: Our model is based on neural representations of different motor actions by mutually coupled neural fields. One field model represents the perceived action (vision field), and the other one the associated motor program (motor field). They consist of coupled ensembles of Exponential Integrate-and-Fire neurons (Brette et al., 2005), and stabilize travelling local solutions (activity peaks), which either follow the stimulus pattern in the vision field, or propagate autonomously after a 'go-signal' in the motor field. Both fields are coupled by interaction kernels that stabilize solutions with synchronously propagating pulses in both fields. Representations for different actions inhibit each other. We used the model to reproduce the results of several experiments focusing on action-perception coupling and mirror neurons. RESULTS: Consistent with experimental data, this architecture provides a unifying account for spatial and temporal tuning of action-perception coupling (Christensen et al., 2011), and for the influence of action perception on variability of execution (Kilner et al., 2003). The model reproduces the behavior of the neural population vector trajectories of mirror neurons in premotor cortex (Caggiano et al., 2016). Duplication of the model architecture allows to reproduce the spontaneous synchronization of two observers that see each other executing periodic body movements (Schmidt et al., 1990). CONCLUSION: The proposed model reproduces, using a single parameter set, a variety of quite different experiments that address the interactions between action vision and action execution. Since the model uses physiologically plausible circuits it makes a variety of predictions at the single-cell level.

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56.4005 **The primacy effect in primate saccade target selection** Jeroen Goossens[1](J.Goossens@donders.ru.nl), Joke Kalisvaart[1], Roohollah Massoudi[1], Peter Bremen[1]; [1]Donders Institute for Brain, Cognition and Behaviour

It is often assumed that decision-making involves neural competition, accumulation of evidence 'scores' over time, and commitment to a choice once its 'scores' reach decision-threshold first. So far, however, neither the first-to-threshold rule, nor the nature of competition, has been revealed by experiments. Here, we presented two simultaneously-flashed targets that reversed their intensity difference during presentation, and instructed subjects to saccade towards the brightest target. Both humans (n=6) and monkeys (n=2) preferentially chose the target that was brightest during the first stimulus phase. Unless this first phase was too short, primacy persisted even if the second, reversed-intensity phase lasted longer. This effect did not result from premature commitment to the initially-dominant target; a strong target imbalance in the opposite direction later on drove nearly all responses towards that location. Moreover, there was a non-monotonic relation between primacy and target imbalance; increasing this imbalance beyond 40 cd/m2 caused an attenuation of primacy.These are the hallmarks of hysteresis, predicted by models in which target-representations compete through strong feedback. Preliminary analysis indicates that the choice behavior is reflected in the timing of visual burst activity of neurons in the Frontal Eye Field; bursts for 'winning' target-representations preceded the 'losing' ones. However, the contrast-dependent changes in burst timing did not result from cross-inhibition; keeping the intensity of the target inside the receptive field of the cell constant while changing the intensity of the opponent target, abolished the latency changes.

Acknowledgement: RadboudUMC

56.4006 **Semantic knowledge and action-based visual prediction** Nicholas Hindy[1](nhindy@princeton.edu), Emily Avery[1], Nicholas Turk-Browne[1]; [1]Princeton Neuroscience Institute, Princeton University

Goal-directed behavior requires predicting the consequences of our actions. Predictions based on specific episodes in our past may arise from pattern completion in the hippocampus, which in turn reinstates the retrieved consequences in visual cortex (Hindy et al., 2016, Nature Neurosci). However, action-based predictions are not always tied to specific episodes, but instead to general semantic knowledge learned pedagogically or aggregated from many experiences over a long timescale. For example, when cracking open an egg we expect to see a yoke. It is unknown how such visual predictions based on long-term semantic memory are generated. We hypothesized that they may also be supported by the hippocampus. To test this hypothesis, we collected high-resolution fMRI data while participants selected among familiar actions that changed the state of one object into another. For the

Novel condition, participants learned actions that changed objects in arbitrary ways (e.g., "point" or "wave" to transform a dollar bill into a carrot or a newspaper), and thus predictions needed to be based on recently experienced episodes. For the Known condition, the outcomes of actions were obvious (e.g., when you "roll" or "fold" a dollar bill) because predictions could rely on pre-existing semantic knowledge. In both conditions, responses in early visual cortex were attenuated when an outcome could be predicted from an action, and this predictive attenuation was related to background connectivity with the hippocampus. Examining the hippocampus more closely, there was a dissociation over the long axis, with Novel prediction in visual cortex related to the anterior hippocampus and Known prediction related to posterior hippocampus. These findings suggest that the hippocampus may mediate visual prediction even based on long-term semantic knowledge, but possibly through different mechanisms than observed for visual prediction based on recent episodic learning.

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56.4007 **Mental state affects visual performance** Yael Afiki[1](yael.afiki@gmail.com), Moshe Bar[1]; [1]Bar Ilan University

Mood affects perception, biases judgment, and disrupts processing. Previous studies have shown that positive mood tends to correlate with broad associative thinking, while negative mood correlates more with narrow associative thinking. Moreover, in the reverse direction, studies have demonstrated that mood improves after processing information with broader associative span. In the present study, we examined this promising link by testing whether visual performance is influenced by associative thinking. We used pairs of associative images (presumably to promote positive mood) and pairs of unassociated images, and tested the effects on three different visual paradigms: 1.contrast sensitivity, 2. global vs. local perception, and 3. critical flicker fusion. In agreement with our hypothesis, our findings suggest that visual perception is influenced by associations (and similarly by mood). We found that associative thinking was accompanied by better visual performance relative to unassociated thinking in all three visual aspects. Thus, it seems that associations have a beneficial effect on visual performance, possibly through the induction of positive mood.

56.4008 **Optimizing Visual Representations: The RotCorr Methodology for Rotating Geometric Multidimensional Scaling Solutions to Align with Meaningful Functional Dimensions** K. Jake Patten[1](kjp@asu.edu), Michael McBeath[1]; [1]Arizona State University

Multidimensional scaling (MDS) is a useful tool for data visualization and nominal classification of stimuli across both abstract and physical dimensions. Researchers often rotate the resulting solution to emphasize primary organizational dimensions. Often, this is the extent of data analysis with MDS; it is uncommon for researchers to confirm their dimensions with either correlation or regression. The current research project illustrates a cross-correlational and dimension optimization procedure we call Rotation and Correlation (RotCorr), which uses a secondary, unidimensional data set to confirm hypothesized dimensions. This procedure does not simply correlate a researcher-rotated MDS solution with a secondary set, it rotates the MDS solution to return the optimal correlation. Using RotCorr to optimize the orientation of an MDS configuration allows researchers to better identify functional MDS dimensions, and provides a direct comparison of overlapping dimensionality of the original and secondary data sets. The RotCorr solution provides both numerical correlation coefficients between the MDS solution and secondary data set, and specifies the multidimensional angle in which to optimally rotate the MDS solution. In so doing, RotCorr elevates MDS from principally a simple, descriptive, ordinal-level data visualization tool up to a more sophisticated, interval-level, numerical statistical procedure. The RotCorr procedure provides advancement in data visualization methodology that can enhance functional visual representations of abstract concepts. The current work also highlights examples of how MDS and RotCorr can be applied to areas of visual research such as face perception and similarity of visual illusion stimuli, such as Ebbinghaus circles and Müller-Lyer lines. Specefically for face perception, MDS and RotCorr revealed facial expression (emotion) to be a main organizing component, even among faces of several different people.

Color and Light: Cognition and Preference

Tuesday, May 23, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4009 **Statistical variations in the power spectrum of daylight over a day predict communicative efficiency of color-language** Sivalogeswaran Ratnasingam[1], Edward Gibson[2], Richard Futrell[2], Julian Jara-Ettinger[2], Kyle Mahowald[2], Leon Bergen[2], Steven Piantadosi[3], Bevil Conway[1]; [1]Laboratory of Sensorimotor Research, National Eye Institute, NIH, [2]Department of Brain and Cognitive Sciences, MIT, [3]Department of Brain and Cognitive Sciences, University of Rochester

All languages appear to distinguish warm colors from cool colors, but the reason underlying this universal color-naming pattern is unknown. Using original data collected in English, Spanish, and Tsimane', along with data from the 110 languages of the World Color Survey, we discovered that all languages convey more information about warm colors (reds, oranges) than cool colors (greens, blues). In this study, we conducted a new simple information theoretic measure of a particular color relative to a set of colors: average surprisal, which allows us to rank the colors for their relative communicative efficiency within a language. We investigate two potential causes for this asymmetry: (1) color statistics of foreground objects versus backgrounds in natural scenes; and (2) statistical variation of daylight spectra at different phase of day. First, using an analysis of 20000 images independently curated for salient objects [1], we discovered that objects have a higher probability of having a warm color than a cool color compared to backgrounds. Second, we discovered that the communication efficiency of a color term is correlated with equivalent corrected color temperature (CCT) of the color of the Munsell chips. Specifically, the color-language communication efficiency decreases with increasing equivalent CCT of the Munsell chips. Further, the CCT of daylight is low during midday and increases during sunrise and sunset [2]. This variation in spectral content of the daylight is largely discounted by the visual system through color constancy operations, although an object's color is most close to the color observed under equal energy light during midday, under low CCT daylight. [1]. Tie Liu, Jian et.al. Learning to Detect A Salient Object. In Proc. IEEE-CVPR, Minnesota, 2007. [2]. Sivalogeswaran Ratnasingam, et.al. Analysis of colour constancy algorithms using the knowledge of variation of correlated colour temperature of daylight with solar elevation. EURASIP, pp 1-13, 2013.

Acknowledgement: NIH

56.4010 **Development of color communication across the life span (3 –75 years).** Delwin Lindsey[1,2](lindsey.43@osu.edu), Angela Brown[2], Nicholas Carr[2]; [1]Department of Psychology, Ohio State University, Mansfield, [2]College of Optometry, Ohio State University

An important aspect of color cognition is the ability of individuals to communicate effectively with others, within their language community, about the colors they see. We studied color communication efficiency in 384 visitors at the Center of Science & Industry in Columbus, OH, who were tested en scene using stimuli presented on calibrated iPad-Air computers. 6–75 year-olds provided monolexemic terms (or "don't know," DK) for 30 colored patches that optimally sampled the World Color Survey stimulus set. Then, each subject viewed all 30 colors at once and identified the color associated with each of their own 30 terms and each of the 30 terms previously provided by another subject (randomly chosen from a large database). We tested 3–5 year-olds using an abbreviated protocol. Data were analyzed using an information theoretic framework. The color naming data were used to estimate each subject's channel capacity (in bits) for color communication. Comparison of each subject's color naming and color identification data (mutual information) estimated communication efficiency (in bits). 3–4 year-olds rarely used more than the 11 English basic color terms (BCTs), and they deployed brown and gray idiosyncratically, a finding consistent with work of others. DK responses were rare beyond age 3 years, and most of the 21 common color terms in the English lexicon (Lindsey & Brown, 2014) appeared by age 6–8 years. Communication efficiency increased by almost a factor of two (0.9 bits) across the life span, with the greatest increase occurring between ages 3–20 years. Improved communication efficiency was due to: 1) increased channel capacity due

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to expanding color lexicon with age and 2) improvement with age in the consistency of color term deployment. Moreover, our results suggest that this improvement continues throughout the life span.

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56.4011 **Ensemble percepts of color contrast** Siddhart Srivatsav[1](sidopto@gmail.com), John Maule[2], Anna Franklin[2], Michael Webster[1]; [1]University of Nevada, Reno, USA, [2]University of Sussex, Brighton, UK

Ensemble coding has been demonstrated for many attributes including color, but the metrics on which this averaging is based remain uncertain. We examined ensemble percepts for colors that varied in saturation along opponent axes, to explore how averaging occurs across saturation within and between hues. Ensembles were composed of 4 chromatic contrasts in equal log steps plus gray. They were displayed as 16 randomly positioned circles, demarcated by black borders from the gray background. Some sets included complementary colors (opposite sides of the same axis) and either did or did not include the achromatic stimulus. The hue axis varied randomly across trials to avoid learning specific colors. Targets included the four displayed contrasts and five additional levels at intermediate or higher contrasts. On each trial observers saw the ensemble for 0.5 sec and after a 1 sec delay responded whether a single displayed target was a member of the set. For sets with complementary colors (e.g. red and green), false alarms for gray targets were lower even when this gray represented the mean chromaticity. Reported membership was instead bimodal for each hue. In unimodal sets (e.g. red or green) false alarms fell precipitously at the gray boundary. These categorical effects suggest that averaging occurs primarily within rather than between complementary hues. In biased ensembles (e.g. red contrasts higher than green) the perceived membership paralleled the asymmetry (e.g. fewer false alarms for high contrast greens). This suggests that hue and saturation are not encoded as independent attributes, and instead is consistent with averaging within each hue. Our results suggest that ensemble percepts of color are not based on a simple metric like Euclidean distance, and that the overall mean of a color distribution with different hues may be available only implicitly, from the summary percepts of the different hues. Funding EY-10834

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56.4012 **Cones and colour: similarity and our perception of cardinal colours** Kaye Mullins[1](kayemu8@gmail.com), Simon Cropper[1], Daniel Little[1]; [1]The University of Melbourne

Generally, it has been assumed that the task of stimulus discrimination differs from that of categorisation; exemplar-based theories challenge this assumption. It was recently shown that both the discrimination and categorisation of cardinal colours may be explained by the same underlying similarity judgement space. Further, we have found that similarity judgement of cardinal colours are best fit by an elliptical deformation of the cardinal colour plane into a perceptually equal space. Here we extend these data by examining how similarity judgements change as the amount of information on each sample is reduced. Observers were required to judge, on a scale of 1-8, the degree of similarity between 210 pairs (21 colours) of scaled, equiluminant cardinal colour patches presented for 100msecs. The paradigm and stimulus structure was exactly the same as used for the previous discrimination and categorisation measurements; only the observer judgement changed. The data were analysed using multi-dimensional scaling to give a psychological similarity space for each subject. We found few systematic differences between the MDS spaces for the same group of subjects as in the longer duration study despite the brief stimuli. We discuss this in terms of exemplar-based theories of categorisation.

56.4013 **Cardinal Colour Recognition: Sensitivity to Similarity-based Mask-Induced Interference?** Amanda Shanks[1](amandaleeshanks@gmail.com), Simon Cropper[2], Daniel Little[3]; [1]The University of Melbourne, Melbourne School of Psychological Sciences, [2]The University of Melbourne, Melbourne School of Psychological Sciences, [3]The University of Melbourne, Melbourne School of Psychological Sciences

Decreases in old-new recognition performance may be due to confusability of items in memory. Hue-dependent mask-induced interference has been shown to affect stored representations of colour stimuli within short-term perceptual memory by reducing the fidelity, or sensitivity, with which information is stored in memory. We manipulated sensitivity using a delayed hue-discrimination paradigm in a recognition memory task. We examined old-new recognition judgments for cardinal stimuli that are embedded in a continuous, multidimensional space. Cardinal colours typically do not have learned colour names and are perceived as desaturated and more perceptually mixed than monochromatic stimuli. Five colour-normal subjects completed the experiment. Stimuli were 8 degree centrally-located patches from the subjectively equiluminant plane of cardinal colour space, presented for 1 sec (500ms half-width) in a raised-cosine temporal-envelope where the inter-stimulus interval between the reference and test stimuli ranged from 0.5ms to 5s. The patches consisted of 14 colours drawn from equally spaced intervals within the ranges 350° to 11° and 34° to 56°. To measure sensitivity, the observers' task was to make same-different judgments for the pair of stimuli. Three types of masks were examined: (1) a mask that was either similar in hue to the study and test items, (2) a mask that was drawn from the opposite region of colour space, and (3) an achromatic (luminance) mask. In the control condition, no mask was presented. The data show the masking conditions had virtually no impact upon similarity-based recognition judgments. These findings are inconsistent with previous studies demonstrating mask-induced interference, particularly when the mask is identical or of a similar hue to the study and test item. These findings suggest that short-term memory for cardinal colours is robust despite the presence of internal (the delay) or external (the mask) noise.

56.4014 **How robust are color-specific biases in memory?** Sarah Allred[1](srallred@camden.rutgers.edu), Dajsha Collins[1], Christina Curtis[1], Jacqueline Gomez[1], Jameira Jackson[1], Sehwan Park[1], Jessica Rumer[1], Hechen Wang[1]; [1]Department of Psychology, Rutgers

Background: Color matching in both perception and memory is reported to exhibit color-specific patterns of bias and variability that have been accounted for by a model in which color categories influence color selections. (Bae et al, 2015). If robust, these patterns may prove a useful tool in understanding how prior information, such as color categories, influences visually-guided behavior when memory makes sensory information increasingly noisy. Methods: We completed two studies. The first (CRT) was a nearly exact replication of the task in Bae et al (2015); the second (RealWorld) was a conceptual replication using real objects. After viewing a test color, observers in both studies selected its match from a hue circle presented either simultaneously (perception) or after a 2 second delay (memory). Between trials, test stimuli spanned the hue circle (CRT: 180 2D patches; RealWorld: Farnsworth-Munsell 100 hue chips). From pooled observer responses, we estimated bias and variability of choices for each test color. Observers' color category estimates were obtained in separate experiments. Results: Reliable patterns of bias and variability were present in both studies. Bias and variability of perceptual matches correlated strongly with bias and variability of memory matches in both CRT and RealWorld studies. In addition, observer-defined color categories made sense of the color specific patterns of bias in the CRT study: Matches to colors near boundaries of categories were biased towards the nearest color category center. Although real-world data were internally reliable, the effect of categories was not clear for real world stimuli. Conclusions: Color-specific patterns in bias and variability of color matches were robust across experiments; however, only for study CRT were patterns consistent with categories influencing visually-guided behavior when sensory information is uncertain.

Acknowledgement: NSF CAREER BCS 0954749 to Sarah Allred

56.4015 **Color naming fluency does not explain color preference when chroma is controlled** Chris Racey[1,2](c.racey1@gmail.com), Karen Schloss[1,2]; [1]Department of Psychology, University of Wisconsin - Madison, [2]Wisconsin Institute for Discovery, University of Wisconsin - Madison

The fluency theory of aesthetics proposes that people prefer stimuli that are easier to process (Reber et al., 2004). This was based, in part, on Martindale and Moore's (1988) evidence that prototypical colors were preferred to non-prototypical colors. However, their color set (from Rosch, 1975) confounded prototypicality with saturation—most of the prototypes were highly saturated and the non-prototypes were less saturated. Recent evidence demonstrated that verbal fluency—operationalized as naming response time (RT)—predicted color preferences of dichromatic and trichromatic males (Álvaro, et al., 2015). However, saturation is known to be related to color preference (Guilford & Smith, 1959; Palmer & Schloss, 2010) and it is possible that saturated colors are both preferred and more easily named, without fluency directly influencing color preferences. We tested whether fluency predicted color preferences when saturation was controlled. We included approximations of the eight prototypes (saturated) and eight non-prototypes (desaturated) from Martindale and Moore (1988). We also included +/-1 and +/-2 hue steps in Munsell space from those initial colors, while controlling value and chroma within each color category. Participants completed a color preference task and color naming task (counterbalanced). In the color preference task participants rated how much they liked each color. In the naming task they named each color as fast as they could. We calculated naming RT as the time between stimulus onset and naming vocalization. Color preferences were related to naming RT in the full dataset ($r=-0.27$, $p< 0.05$), but the relation was eliminated when chroma was partialed out ($r=-0.13$, $p =0 .263$). Within the saturated set where prototypically only varied by hue, participants were faster at naming colors that were closer to the prototype ($r=0.33$, $p< 0.05$), but there was no such relation between prototypicality and color preferences ($r=-0.06$, $p=0.714$). These findings suggest fluency may not causally influence color preferences.

56.4016 **Kandinsky or me? How free is the eye of the beholder in abstract art?** Doris Braun[1](doris.braun@psychol.uni-giessen.de), Katja Dörschner[1]; [1]Justus-Liebig University, Dept. of Psychology, Giessen

Abstract artworks represent a complex composition of shapes, colors and graphic elements. Research of art perception has focused often on aesthetic ratings. Here we take a different approach and investigate abstract art perception by assessing (i) how the artist's color palette of a painting influences observers' choice of color for one element in the same painting (ii) if observers prefer their color choices over the original and (iii) how the composition of the painting affects its perceived balance. Participants (i) adjusted, starting with a neutral gray, the color of a single shape selected in 24 abstract paintings of Baumeister, Hoffmann, Delauney, Kandinsky and Klee, and indicated (ii) their preference between the original painting or with the adjusted color. To measure the perceived balance (iii) in a painting we asked participants to indicate the center of gravity for each artwork by adjusting the location and size of a black circle on a corresponding adjacent white rectangle. Our results show that, color settings are frequently not in agreement with the artist's choice but differ significantly from the distribution of randomly picked CIE-LAB samples. Notably, the color palette of a painting influences color choices in two ways: it either elicits harmonious or contrasting settings. Unlike for color settings observers' exhibited a remarkable consistency in their perceived center of gravity. Having seen a painting once influences quite effectively whether the original or its mirror image is preferred.

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56.4017 **The role of perceived opacity in interpreting colormap data visualizations** Madeline Parker[1,2](mparker23@wisc.edu), Allison Silverman[3], Audrey Wang[4], Karen Schloss[1,2]; [1]Department of Psychology, University of Wisconsin-Madison, [2]Wisconsin Institute for Discovery, University of Wisconsin-Madison, [3]Science and Society Program, Brown University, [4]Applied and Computational Mathematics, California Institute of Technology

Interpreting data visualizations requires determining how perceptual features are assigned to semantic concepts. For example, interpreting colormaps requires inferring how dimensions of color correspond to quantities of a given measure (e.g., brain activity, correlation magnitude). This process should be easier when percept-concept assignments in visual displays (specified by legends/labels) match predicted percept-concept assignments in observers' minds (perceptual-cognitive fit). But, what are the predictions in observers' minds? Evidence suggests observers predict darker colors correspond to larger quantities—response times (RTs) to interpret colormaps are faster when legends specify dark-is-more rather than light-is-more assignments (Silverman et al., VSS-2016). This pattern was largely unaffected by contrast with the background. However, the background may have an effect when the colormap appears to vary in opacity (e.g., value-by-alpha maps; Roth et al., 2010). To test this hypothesis, we presented participants with fictitious data matrices in which columns represented time, rows represented animal species, and cell color represented number of animals sighted during each time window (as in Silverman et al., VSS-2016). Participants reported when more animals were sighted (early/late) and we measured RTs. We used 3 kinds of colorscales to construct the colormaps [black-white/black-blue/white-blue], which appeared on 3 possible backgrounds [black/white/blue], with 2 possible lightness-quantity assignments in the legend [light-is-more/dark-is-more], 2 legend orientations ["greater" labeled higher/lower in the legend] and 20 replications (720 trials). Under conditions in which the colorscale faded into the background (e.g., white-blue scale on a white or blue background), RTs revealed interactions between lightness-quantity assignments in the legend and background lightness (all $ps< .01$). RTs were generally faster when the legend specified dark-is-more on light backgrounds as shown before, but this difference either diminished or reversed on dark backgrounds (opaque-is-more bias). The results suggest the opaque-is-more bias overrides the dark-is-more bias when there is perceptual evidence for varying degrees of opacity.

56.4018 **Trump makes us "see red"; Clinton makes us "feel blue"** Adam Greenberg[1](agreenb@uwm.edu), Alysan Stauffacher[1]; [1]Department of Psychology, University of Wisconsin-Milwaukee

United States political affiliations run deep in modern times. Recent work has shown that even color preferences modulate on election day through a strengthening of Democrats' preference for blue, and Republicans' for red (Schloss & Palmer, 2014). These results were obtained through overt reporting of color preference and political affiliation and, therefore, may be subject to explicit attitudes and biases. Here, we measured whether color preferences reflect more implicit biases using a flanker task with irrelevant colors. We tested 451 subjects through Amazon's Mechanical Turk: approximately half in early July of 2016, and the other half on election day (November 8, 2016). Five alphanumeric characters appeared horizontally at display center. The middle letter always contained either an 'S' or 'H' target rendered in white, and subjects ignored the four flanking letters. Subjects identified the target via computer keyboard. We adopted a 2 x 3 factorial design with two flanker colors (red, blue) and three target-flanker shape compatibilities (compatible, neutral, incompatible), randomized within blocks. After the flanker task, subjects were queried about color preference and political party affiliation. On election day (versus non-election days), we found increased preference for Blue amongst Democrats and decreased preference for Blue amongst Republicans, while Red preferences were unchanged, consistent with previous findings. Interestingly, Independents showed increased Red preference and no change in Blue preference. On election day (versus baseline), both Democrats and Republicans revealed no change in flanker compatibility effects (incompatible – compatible RTs) for flankers rendered in their respective party colors. However, Democrats were significantly more affected by Red flankers (and Republicans by Blue flankers) on election day. Independents displayed increased flanker effects for both flanker colors on election day. Together, these results suggest that effects of political affiliation on color preference are implicit in nature and may dynamically alter fundamental perceptual and cognitive processes.

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Color and Light: Thresholds

Tuesday, May 23, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4019 **Effect of blur in colour discrimination** Leticia Álvaro[1](Leticia.Alvaro@anglia.ac.uk), João Linhares[2], Talia Ali[1], Monika Formankiewicz[1], Sarah Waugh[1]; [1]Anglia Vision Research, Vision and Hearing Sciences, Faculty of Science and Technology, Anglia Ruskin University, Cambridge CB1 1PT, United Kingdom, [2]Centre of Physics, Campus de Gualtar, University of Minho, 4710-057 Braga, Portugal

Blur impairs colour discrimination but this impairment has not been systematically investigated across hue. In this work we obtained colour discrimination thresholds for a number of hue angles, stimulus sizes and blur levels. A colour discrimination task (Linhares et al., 2016 JOSA A 33(3): A178-A83) was performed on a calibrated CRT monitor controlled by a ViSaGe-MKII. A square chromatic target was presented on an achromatic static luminance noise background. Observers indicated the location of the square (right or left). Discrimination thresholds were measured on repeated occasions using a staircase procedure for each of 22 hues, including those from protan, deutan and tritan confusion lines (Smith and Pokorny, 1975 JOSA A 15(2): 161-171). Four observers with corrected-to-normal visual acuity per-

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formed the task monocularly without blur and with four levels of refractive blur: +1 to +4D for 1 deg target, and +2 to +8D for 5 deg target. Colour differences (ΔE^*uv) between target threshold and background were then calculated. The effect of blur was estimated from the difference in ΔE^*uv between the blur and no blur conditions. A repeated measures ANOVA (size, blur and hue) revealed significant size*blur ($P < 0.001$), size*hue ($P < 0.001$) and blur*hue ($P < 0.05$) interactions. Blur affected colour discrimination more for the smaller target, where thresholds were lower. Tukey post-hoc analysis revealed a significant worsening in hue discrimination with blur for yellowish hues near the tritan confusion line when compared to hues near the protan and deutan confusion lines. The effects of lens blur on wavelength transmission as measured with a spectro-photometer (PR650) cannot explain these results. Our results may hold implications for colour vision research especially in developing, aging and diseased populations for whom uncorrected refractive error could mimic losses along the tritan confusion line.

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56.4020 Spectral Sensitivity Functions Derived from Decrement Thresholds

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Spectral sensitivity functions derived from increment threshold (IT) data have long been used to reveal the presence of opponent color interactions. Narrow band stimuli presented for long periods on bright achromatic backgrounds produce spectral sensitivity functions with large contribution from opponent channels while smaller fields on dim backgrounds presented quickly, or with fast flicker, result in the luminosity function with little to no evidence for opponent interaction. Although IT derived functions have been studied extensively, little attention has been paid to spectral sensitivity functions derived from decrement thresholds, largely due to the technical challenges. Decremental sensitivities are interesting for several reasons: 1) many if not most of the differences between surface colors in the real world are produced by decremental changes as light is differentially absorbed by pigments; and 2) there are known asymmetries in the visual system between on- and off-pathways and between incremental and decremental responses within these pathways. We measured increment and decrement sensitivity functions in subjects under conditions designed to produce strong contribution from opponent pathways. Preliminary results reveal that in many subjects, increment and decrement derived spectral sensitivity differed systematically. In particular, it appears that the decrement sensitivity curves reveal less contribution from the L-M opponent inputs relative to the S-(L+M) input.

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56.4021 Nonlinearity of contrast responses in human achromatic and color vision

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The transduction mechanisms in the visual system are nonlinear. In pedestal masking the detection of contrast increments is facilitated at low pedestal contrasts and masked at high pedestal contrasts. Hence increment thresholds measured over a range of pedestal contrasts form a "dipper" function whose shape reflects the underlying contrast response function (CRF). Here, we exploit this relationship to measure the CRFs for achromatic and isoluminant red-green (RG) color contrast. Contrast increment thresholds for Gabor patterns (0.375 c/deg, 2 Hz) with either achromatic or isoluminant RG (L/M cone opponent) contrast were measured for three observers in a pedestal masking paradigm. CRFs were fitted to the individual trial responses using maximum-likelihood fitting: response = (contrast^p)/(z+contrast^q). Although cone contrast sensitivity was on average 4.91±0.62 times higher for the isoluminant RG stimuli, the shapes of the dipper functions for the two conditions were similar. The fitted transducer parameters (p and q) were found to be similar across the achromatic and RG chromatic CRFs. Between three subjects, average p values of 2.36±0.47 and 2.38±0.41 were found for achromatic and chromatic CRFs, respectively. The respective q values were 1.91±0.41 and 1.87±0.30. Regardless of individual sensitivity differences, these similarities between achromatic and color perception are consistent within each subject. We find that the shapes of the CRFs for achromatic and RG color contrast are very similar. This is important for studies that normalise the contrast responses to achromatic and color stimuli by scaling them in multiples of detection threshold. Differences in the shapes of the CRFs would make this normalisation method invalid. Future CRF measurements for achromatic stimuli at higher temporal rates (0.375 c/deg, 10 Hz) will be used to compare the supposed "magnocellular" CRF against the "parvocellular" CRFs measured here.

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56.4022 Explaining 'crispening' as a gain control mechanism.

David Kane[1](kanepsychophysics@gmail.com), Marcelo Bertalmío[2]; [1]Universitat Pompeu Fabra

Sensitivity to variations in luminance has been extensively studied via detection thresholds to give the well-known threshold versus intensity (TvI) function. The function is expansive – the lower the luminance level, the lower the threshold. However, when a pedestal is introduced such that the task is to discriminate between the luminance of two patches superimposed upon a uniform background, the results are substantially more complex. Thresholds are both low at the lowest luminance levels tested and additionally around the background luminance level, an effect termed 'crispening'. This has lead authors to propose two separate mechanisms, one more sensitive to low luminance levels and another to contrast around the background luminance level. In this paper, we model discrimination thresholds via a single mechanism. We assume that the maximal sensitivity of the HVS is well modeled by the shape of the TvI function, but in the case of non-uniform backgrounds this function is modulated by a gain control mechanism that increases thresholds away from the background luminance level. We evaluate our model upon the data of Paul Whittle (1986) who examined discrimination threshold over a broad luminance range and also upon new and old data for functions exhibiting various levels of 'crispening' (Nagy and Kamholz, 1995). Second, in keeping with the work of Paul Whittle (1992) we investigate whether this model can predict supra-threshold brightness functions. We find that as long as a realistic (a non-Weber) TvI function is used, that the brightness functions can be accurately estimated. In the case of non-uniform backgrounds (salt and pepper noise or the inclusion of an annulus), the model requires an additional gain term for each background luminance level. Although this adds to the complexity of the model, it offers the possibility of extending the model to arbitrarily complex stimuli.

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56.4023 Transient lumanopia at night

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Rods recover sensitivity after turning off a light-adapting field, an effect known as dark adaptation. Recovery is assessed behaviorally by measuring the threshold for just detecting a test flash on the field, compared to just after turning the field off. In the present experiment, tests were presented for 2s and flickered at 4 Hz or 8Hz (100% modulation). Subjects adjusted test radiance to bring the flicker to threshold. Flicker thresholds at 4 Hz recovered 600 ms after turning off a dim (0.00158 sc td) field, paralleling the recovery found for detections. However, flickers at 8 and 10 Hz did not recover after turning off the field, but needed intensification to become visible. In this respect the rod pathway parallels the cone pathway, as cone-mediated luminance flickers also recover at lower Hz but rise at higher Hz (Reeves & Wu, Vis. Res., 2004). We had named this effect 'transient lumanopia' as it is reminiscent of transient tritanopia in the yellow-blue pathway and its analogues in the red-green pathway. Current data show that transient lumanopia is a property of the entire luminance pathway, not just of the photopic branch, and add to the remarkable series of phenomena in which visual sensitivity decreases, not increases, in early dark adaptation.

Acknowledgement: none

56.4024 Gaze behavior during the averted detection of a simulated faint star

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Vision in daytime conditions relies on pointing one's fovea to successive targets of interest. Looking directly at visual targets may not be the best strategy to acquire information in nighttime conditions, however, because rods (which mediate night vision) are absent from the fovea. Here we explored the relationship between eye movements and perception in scotopic conditions, with a technique first proposed around 325 BC and still used today, known as "averted vision." Looking away from faint celestial objects, instead of directly at them, can improve their detection. The reason is thought to be that light falls on more rods as the objects approach ~20° of visual angle away from the center of gaze. No studies have determined the pattern of averted vision that best facilitates perception, however. We assessed averted vision while recording eye positions of dark-adapted human participants, for the first time. We used a CRT monitor and a series of three neutral density filters to create a centrally-placed dim artificial star, of apparent magnitude 4.2 (dimmer than Tau Ceti). After dark-adapting, participants (n=12) made eye movements to a series of fixation targets, viewed binocularly. Participants made a yes/no judgment about whether the star was visible at each fixation location. This provided a map of detection performance in all directions surrounding the star. If rod-cone distribution was the sole predictor of performance, we should have found peak performance 20° away from the star and a linear improvement as gaze approaches 20°. Contrary to this prediction, our participants' accuracy peaked around 10°, and decreased at greater distances. This work may provide a better understanding of rod function, and in turn lead to improved screening and assistive technologies for eye movement and night vision disorders.

Acknowledgement: Empire Innovator Program, State of New York

56.4025 Relation between Pupil Response and Feedback during Contrast Sensitivity Measurement through Tinted Lenses

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It has been reported that yellow tinted lenses increase the pupil size and it is questionable, if the resulting pupillary light response (PLR) influences the visual performance. The PLR reflects not only the amount of light entering the eye, but also cognitive factors such as visual attention and awareness. The aim of this study was to investigate the relation between pupil response and the presence of an acoustic feedback on contrast sensitivity (CS) measurements under tinted lenses. A CS-test determined the threshold contrast using a sine wave grating at 0.5, 1.5, 3 and 6 cycle per degree each with 50 trials. This CS-test included an adaptive staircase (Ψ-method), a 16-bit gray-level resolution and acoustic feedback indicating correctness. The stimulus was surrounded by a white annular scatter source (adapted from Oculus C-Quant) in order to induce a PLR recorded with an eye-tracker (EyeLink-1000-Plus). CS and PLR were measured monocularly in five experienced participants wearing orange, green, violet and yellow tinted lens under equi-luminant conditions. The relative PRL was averaged over participants and tested spatial frequencies. Relative PLR amplitude was significantly different ($p < 0.001$) in an ANOVA for the conditions with and without acoustic feedback. In conditions with feedback, this difference in relative PLR was larger for orange and yellow tinted lenses compared to no filter conditions ($p < 0.01$). The CS measured with acoustic feedback showed no significant improvement compared to no-feedback conditions ($p=0.12$), although this could be expected due to attentional fluctuations and PLR change. However, there was a tendency for an impact of feedback on CS at lower spatial frequencies. This study suggests a positive relation between pupil response and acoustic feedback during contrast sensitivity measurements. In conclusion, orange and yellow tinted lenses showed a larger PLR, suggesting a direct attentional effect of acoustic feedback on pupil response.

56.4026 The effect of TMS intensity on contrast sensitivity

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Transcranial magnetic stimulation (TMS) is a popular tool to study cognition. However, the manner in which TMS actually affects neuronal populations remains unclear. One theory postulates that TMS works similarly to an input-gain model, while opposing views posit that it acts as a noise inducer under the principle of stochastic resonance. Extending the work of Perini et al. (2012), we sought to investigate whether graded levels of visual contrast are differentially affected not merely by TMS, but rather by varying levels of TMS intensity. Methods. Single pulse TMS was delivered to left V1 while participants performed a 2-AFC orientation discrimination (OD) task of one of two Gabor patches presented on either side of fixation at 5 contrast levels and 4 TMS intensities. We analyzed behavioral performance using a 3-way repeated-measures ANOVA and fitted Weibull parameters to the psychometric functions in order to assess whether TMS affected discrimination thresholds. Results. Participants' performance of OD improved with increasing stimulus contrast, irrespective of TMS intensity, and both visual fields were affected by TMS, with increasing TMS intensity yielding decreasing performance at different contrast levels. Additionally, we found an interaction between the effects of TMS intensity and stimulus contrast, wherein increasing TMS intensity decreased performance predominantly at the middle contrast levels. Parameter fitting demonstrated that TMS intensity at 100% yielded decreased contrast sensitivity thresholds in both visual fields compared to the no TMS condition. Summary. Building on the findings of Perini et al. (2012), our results suggest incremental levels of TMS pulse strength yield a gradient-like decrease in performance. These findings contradict previous work which led to the belief that TMS intensity behaved in a relatively linear manner. Overall, our findings cannot corroborate a dichotomous account of TMS in which high and low intensity pulses are confined to their own distinct categories of effects.

56.4027 Effects of Size and Shape on Perceived Color Differences

Danielle Szafir[1](dalbers@cs.wisc.edu); [1]University of Colorado Boulder

Most of our understanding of color difference perception is grounded in studies of colored patches of uniform size and shape. However, our ability to distinguish between colors depends on the spatial properties of objects being compared. This work statistically models how variations in size and shape change people's abilities to perceive color differences between two objects. Our models describe color difference perception as a function of how frequently people can correctly identify a difference between patches at fixed color distances for three patch shapes---circles (as in points on a scatterplot), lines (as in lines in a line graph), and rectangles (as in bars on a bar chart)---ranging in size from 0.125 to 6 degrees. We derive these models from a set of binary forced-choice comparison experiments conducted using 378 participants across 29,862 trials. These experiments presented participants with a sequence of paired colored patches represented as marks on a visualization. Each pair of patches had a known width and height and a controlled color distance between them. We found an inverse relationship between color discriminability and diameter for circular patches and between discriminability and line height for lines. Our results indicate that color differences are more readily perceived on lines than on circles of equivalent height; however, these gains are not proportional to the corresponding area differences between these patches. Instead, discriminability for rectangles and lines varies according to a weighted combination of the length of the longest edge and the ratio between edge lengths. Our results provide evidence of a direct correlation between the spatial properties of objects and their perceived colors. The corresponding models can be used to predict how the visual system's ability to distinguish colors changes based on the size and dimensions of objects being compared.

Attention: Attentional blink

Tuesday, May 23, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4028 Temporal grouping enables selection of multiple targets in rapid streams of visual information

Guy Snir[1](snirguy@gmail.com), Yaffa Yeshurun[1]; [1]University of Haifa

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When two targets are embedded in a rapid serial visual presentation (RSVP) the ability to report the second target (T2) is impaired if it is temporally close to the first target (T1): The attentional blink. This deficit diminishes with consecutive targets, even if three targets are employed. However, T1 identification deteriorates (a cost) when trailing targets are spared from the blink. The present study evaluated a theory that addresses both sparing and cost effects. The theory suggests that sequential stimuli are represented together in volatile "snapshots" formed during an initial processing stage. Within a snapshot, the representational quality of stimuli decays as they grow "older". A snapshot may be selected and sent to a limited-capacity processing stage where stimuli are differentiated and consolidated. With multiple-target RSVP, snapshot selection is subject to strategic constraints: Early selection might prevent identification of later targets, while late selection might prevent individuation of early targets. These principles suggest that T1 identification would deteriorate with successful identification of consecutive targets, and that snapshot selection timing would vary with the temporal distribution of targets. Experiment 1 tested these predictions using streams with different target distributions (T1T2T3, T1T2DT3, T1DT2T3; D=Distractor). As predicted, regardless of stream type, T1 identification was better when earlier snapshots were selected. Additionally, different distribution of targets led to different patterns of snapshot selection. The theory suggests that early targets are missed because their representational quality is low when selection occurs, whereas late targets are missed primarily because they appear after selection. Thus, manipulating the targets' representational quality should have the strongest effect on T1 identification and the weakest effect on T3 identification. This prediction was confirmed using manipulations of target-distractor discriminability and the targets' presentation time in Experiments 2 and 3, respectively. Overall, the results support a temporal grouping account of selection in the attentional blink procedure.

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56.4029 Is the emotional blink just an attentional blink in disguise? Alyssa Lompado[1](alompado@udel.edu), Daniel Charytonowicz[1], Kaitlyn Naismyth[1], James Hoffman[1]; [1]Psychological & Brain Sciences, College of Arts & Sciences, University of Delaware

Emotionally charged stimuli rapidly capture our attention even when we are deeply engrossed in other activities. For example, when people are searching for a target picture in a rapidly presented stream of scene pictures, they often fail to detect it when it is preceded by a task-irrelevant negative emotional picture, a phenomenon known as "emotion-induced blindness" or EIB (Most, Chun, Widders, & Zald, 2005). This phenomenon appears to be similar to the attentional blink (AB) in which two task-relevant targets appear close in time. The first target is virtually always detected while the second one is often missed if it closely follows the first. One theory of AB holds that targets compete for access to a limited-capacity bottleneck process that stores targets in working memory, This account is supported by the finding that the P300 component which may reflect consolidation into working memory is suppressed and/or delayed for a target appearing shortly after another target. Kennedy, Rawding, Most, and Hoffman (2014) reported a similar result for EIB suggesting that AB and EIB may result from the same mechanism. However, Kennedy and Most (2015) recently reported a result that might challenge this conclusion. They found that lag 1 sparing does not occur in EIB even though it is often observed for AB, which could point to an important difference between them. We directly compared EIB and AB for the case of lag 1 sparing using very similar stimuli. In addition, we recorded ERPs in both paradigms to provide additional evidence on potential differences in the suppression mechanism. We found that lag 1 sparing was absent in both paradigms and that ERP measures of this suppression were remarkably similar, suggesting that the emotional blink may just be an attentional blink in disguise.

56.4030 Does Crossmodal Attentional Blink Depend on Spatial Congruency? Amanda Sinclair[1](ajs857@mail.usask.ca), Jordin Tilbury[1], Steven Prime[1]; [1]Psychology, University of Saskatchewan

Although the majority of research on Attentional Blink (AB) have used purely visual targets, several studies have shown crossmodal AB between visual and auditory targets (e.g., Arnell & Joliceur, 1999; Arnell & Larson, 2002). AB has also been demonstrated with spatially incongruent visual targets (Jefferies & Di Lollo, 2009; Visser et al, 1999). Little is known regarding the effect of spatial congruency in audiovisual AB. Here, we compared unimodal AB and crossmodal AB effects under spatially congruent (targets at same location) and spatially incongruent (targets at different locations) conditions. Targets in unimodal conditions were either purely visual or purely auditory. Crossmodal conditions consisted of either the visual target preceding the auditory target or the auditory target preceding the visual target. In Experiment 1, subjects were tested in all four unimodal and crossmodal conditions with spatially congruent stimuli: visual stimuli were presented in a single stream at fixation and auditory stimuli were presented to both ears over headphones. For Experiment 2, spatial congruency was manipulated by separating the stimuli into two visual streams (left and right of fixation) and two auditory streams (presented to different ears) presented simultaneously. Targets in the unimodal and crossmodal conditions were presented either in the same or opposite side. Our results in both experiments show all unimodal and crossmodal conditions yielded an AB regardless of spatial congruency, but they differed in regards to Lag 1 sparing and magnitude of the AB. AB magnitude was the strongest in the congruent unimodal visual condition and the weakest in the crossmodal condition with visual T1 and auditory T2 in both congruent and incongruent conditions. Lag 1 sparing occurred only when T2 was visual regardless of T1 modality and spatial congruency. Our findings provide new insight into attentional interference across space and sensory domains.

56.4031 The attentional blink reveals discrete perceptual transitions, whereas both spatial and temporal cueing show graded attentional effects Christopher Asplund[1,2](chris.asplund@yale-nus.edu.sg), Joan Ongchoco[1], Gwenisha Liaw[2], John Reid[1]; [1]Division of Social Sciences, Yale-NUS College, [2]Singapore Institute of Neurotechnology

Visual attention can be deployed across space or time, potentially altering the appearance or probability of perceiving stimuli. Carrasco, Ling, & Read (2004) showed that spatial attention increased the perceived contrast of Gabor patches, whereas Asplund et al. (2014) showed that temporal attention affected only the probability of perceiving a color or face target in the attentional blink. Here we adopted Carrasco et al.'s psychophysical approach and stimuli to test whether temporal attention--altered either with cues or the attentional blink--could also have graded effects on conscious perception. After replicating the spatial attention findings, we used rapid serial visual presentation (RSVP) streams of Gabor patches to explore the effects of temporal attention. On each trial, participants reported how many obliquely angled, target Gabor patches were present (0, 1, or 2), and, when two were reported, which patch had the higher contrast. In a temporal cueing experiment, four-dot cues presented 120 ms before one of the targets increased its perceived contrast. In an attentional blink experiment, however, lag (3 or 8) affected only the number of perceived Gabors, not their relative perceived contrasts. These findings support the idea that different forms of attention can affect perception in a graded fashion, particularly at earlier stages of visual processing. By contrast, the attentional blink represents a limitation at central stages of visual cognition, where conscious perception emerges in an all-or-none fashion.

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56.4032 How the perceived duration depends upon the target detection in attentional blink display. Makoto Ichikawa[1](-michikawa@chiba-u.jp), Masataka Miyoshi[2]; [1]Faculty of Letters, Chiba University, [2]Graduate School of Humanities and Social Sciences, Chiba University

It has been known that the perceived duration for a given period decreased with the decrement of number of perceived events during the period. We examined whether failure to detect targets in RSVP (Rapid Serial Visual Presentation) display, which indicate the reduction of perceived frames, causes the reduction of perceived duration by the use of attentional blink paradigm. In each trial, two series of RSVP display were presented one after another at the center of CRT; in each of the RSVP display, two black numerals (1.47 x 1.47 deg) were presented as targets on gray background within a series of black uppercase alphabets. The length of each RSVP display ranged from 17 to 20 frames. Each frame was presented for 70 ms with 23 ms of inter stimuli interval. The lag between the two targets was 1, 2, or 3 frames in one of the RSVP display while the lag between the two targets in the other series was 7, 8, or 9 frames. Ten female and eight male university students took part in this experiment. They were asked to identify the targets for each of the RSVP display, and to report which of the two RSVP displays were perceived as longer. Each participant had 160 trials. We found that the perceived duration for the RSVP display was reduced when participants failed to detect the second target although it was constant when they failed to detect the first target. These results suggest that the way to determine the perceived duration depends upon which target is missed. That is, when the second target is missed (that is, when the attentional blink is observed), the perceived duration varies with the number of perceived frames, while, when the first target is missed, the duration for the missed target is perceptually completed.

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56.4033 **The perceptual enhancement by spatial attention is impaired during the attentional blink.** Bae Eunhee [1](eunhee7b@gmail.com), Jung Shinyoung [1], Han Suk Won [1]; [1]Department of Psychology, Chungnam National University, Daejeon, Korea

Attention operates at multiple processing stages. Specifically, attention enhances weak sensory signal at the perceptual stage, while it also serves to consolidate sensory representations into working memory at the central stage. The present study tested the interaction between these distinct types of attention. In the first experiment, participants were required to detect a target letter (target 1, T1) imbedded in a rapid serial visual presentation of digit distractors. The centrally presented RSVP was followed by another visual task of identifying the orientation of a Gabor grating (target 2, T2) presented in periphery. Importantly, the grating was preceded by a cue stimulus (green outlined square), which was presented either at the T2 location (valid) or elsewhere (invalid). The probability that the cue and T2 locations match was chance (25 %), rendering the cue non-informative of the T2 location. We also manipulated the SOA between the T1 and cue presentations (200 ms vs. 900 ms). The results showed that when the T1-cue SOA was long, T2 accuracy for the valid trials was significantly greater than for invalid trials, $p < .005$, revealing a significant perceptual effect of the spatial attention cue. By contrast, such perceptual effect of attention was not observed when the SOA was short, $p > .22$, indicating that the process of encoding the T1 into working memory impaired the perceptual enhancement by spatial attention. In a second experiment, the T2 was surrounded by distractors, evoking the target location uncertainty and stimulus-driven competition. In this case, contrary to Experiment 1, the effect of spatial cue was invariant of the T1-cue SOA, p's < .01. These results suggest that the perceptual enhancement of attention in the absence of distractors depends on the availability of processing resources recruited for working memory encoding, whereas the noise reduction process by attention does not.

Acknowledgement: This work was supported by the Brain Korea 21 Plus Project in 2016.

56.4034 **First unitary, then divided: The temporal dynamics of dividing attention** Lisa Jefferies[1, 2](L.Jefferies@griffith.edu.au), Joseph Witt[1]; [1]Griffith University, [2]Menzies Health Institute, Queensland

Whether focused visual attention can be divided has been the topic of much investigation, and there is a growing body of evidence that, at least under certain conditions, attention can be divided and deployed as two or more independent foci. Three experiments were conducted to examine whether attention can be divided from the outset or whether, instead, attention is divided gradually over time. To this end, we adapted the methodology of Jefferies, Enns, and Di Lollo (2015), who utilised a dual-stream Attentional Blink paradigm and two pairs of letter targets. One component of the AB, Lag-1 sparing, is known to occur only if the second target-pair appears within the focus of attention. By presenting the second target-pair at various spatial locations, we were thus able to probe the spatial distribution of attention. By systematically manipulating the stimulus-onset-asynchrony between the targets, we were also able to track how the spatial distribution of attention changed over time. The results showed clearly that even under conditions which encourage the division of attention, the attentional focus is first deployed briefly in unitary form before being divided. Our findings also showed that, consistent with previous findings, attention could only be maintained in divided form briefly before settling on a single location (see Dubois, Hamker, & VanRullen, 1997). The present findings suggest that although attention can be divided, it is divided for an even more transient period than has previously been thought, suggesting that a unitary focus of attention may be the "default" mode of attention.

56.4035 **Attentional blink as a product of attentional control signals: A computational investigation** Rakesh Sengupta[1,2](qg.rakesh@gmail.com), Omar Abid[1], Asheer Bachoo[1], John Tsotsos[1,2]; [1]Department of Electrical Engineering and Computer Science, York University, Toronto, ON, Canada, [2]Center for Vision Research, York University, Toronto, ON, Canada

Although there are several different hypotheses regarding the origin of attentional blink, including interference, inhibition, and attentional capacity based explanations, largely, there have been few attempts to cohesively understand attentional blink from a single unified visual-attentive processing model. In the current work we have chosen Cognitive Programs model of visual processing (Tsotsos et al, 2014) in order to illustrate how attentional blink arises from executive control signals of visual-attentive module and visual working memory module. We have computationally simulated the rapid serial visual presentation (RSVP) tasks detailed in Raymond et al. (1992) using letters and oriented bars in order to capture important features of attentional blink. The novel aspect of our work is that in our work attentional blink arises as a by-product of visual processing and attentive control other than less parsimonious accounts of attentional blink.

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56.4036 **Power Modulation in Spatially-Selective Alpha-band Responses during the Attentional Blink** Mary MacLean[1](mary.maclean@psych.ucsb.edu), Thomas Bullock[1], Barry Giesbrecht[1,2]; [1]Institute for Collaborative Biotechnologies, University of California Santa Barbara, [2]Psychological & Brain Sciences, University of California Santa Barbara

The ability to identify a second target (T2) embedded in a rapid serial visual presentation (RSVP) is impaired when T2 is presented at shorter lags following the first target (T1) than at longer lags – an attentional blink (AB). We investigated whether the responses of spatially selective neural populations are modulated by attending to T1, and whether this modulation relates to the AB. We used an inverted encoding model to estimate location-selective neural population responses from scalp recorded EEG in the alpha-band as a measure of selective spatial attention. Participants monitored RSVP streams of alphanumeric stimuli presented in the periphery. The angular rotation of the RSVP locations encircling central fixation varied from trial-to-trial (0˚:60˚:360˚). T1 was a color singleton arrow. Participants either attended both T1 and T2 ($n = 15$), or ignored T1 and attended only T2 ($n = 7$). T2 ('X' or 'K') only ever appeared in the center RSVP stream at either lag 3 or 9. An AB was observed when T1 was attended ($p < .001$), but not when T1 was ignored ($p = .899$). When T1 was attended we observed an increase in the slope and power of the location-selective neural responses relative to the pre-T1 period (% change) – i.e., a "boost" in selective spatial attention from ~100 to 440 ms following T1. Critically, while we observed this "boost" on trials where T1 and T2 were correctly identified, on trials where T1 was correct but T2 incorrect there was a decrease in power. This effect was modulated by lag (T2 performance x lag, $p < .05$). Our results indicate that attending to T1 modulates both the slope and power of location-selective neural population responses in the alpha-band. Furthermore, this post-T1 modulation of power changes with T2 performance accuracy as a function of T1-T2 lag – i.e., an AB.

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56.4037 **Salient Distractors cannot be suppressed during the attentional blink** John Gaspar[1, 2](jmgaspar@ucdavis.edu), Hayley Lagroix[1], Pierre Jolicoeur[3], John McDonald[1]; [1]Department of Psychology, Simon Fraser University, British Columbia, Canada , [2]Center for Mind and Brain, University of Davis, California, USA, [3]Department of Psychology, University of Montreal, Montréal, Canada

Observers can suppress salient-but-irrelevant distractors when searching for a pre-specified visual target. We hypothesize that this salient-signal suppression process is shaped proactively by the observer's attentional set and is largely dependent on the current availability of top-down attentional control. Here, we asked how a temporal disruption of attention control would affect this ability to suppress salient-but-irrelevant distractors during visual search. In order to manipulate attentional control, we used an attentional blink paradigm in which the first target (T1) was a num-

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ber within an RSVP stream of letters and the second target (T2) appeared within a visual search array that also contained a salient distractor. We examined ERPs elicited by various configurations of the T2 search array at lag 2 (within the attentional blink) and lag 8 (outside of the attentional blink) to independently track selective processing of target and distractor. During the attentional blink, an ERP component associated with target selection (the N2pc) was delayed by ~35 ms. In contrast, an ERP component associated with distractor suppression (the distractor positivity; PD) was absent entirely. These results suggest that if the search array appears while the system is busy processing T1, (i) search for T2 is put on hold until after processing of T1 is complete; (ii) distractor suppression is not possible. On this basis, we conclude that the salient-signal suppression indexed by the PD is highly vulnerable to disruptions of attentional control.

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56.4038 **Beneficial effect of exposure to fragrances on attentional blink**

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Recent studies have suggested that aromas can affect the allocation of attention in space and time. For example, Colzato et al. (2014) demonstrated that attentional blink, which refers to a deficit in reporting the second of two targets presented in close temporal succession, is affected by aroma. Specifically, participants exposed to a relaxing lavender aroma showed a less pronounced attentional blink than did those in an odorless room. However, a more pronounced attentional blink was observed when participants were exposed to a more stimulating peppermint aroma. These findings suggest that environmental factors, such as aromas, contribute to the allocation of temporal attention. The present study extended these findings in two ways: it demonstrated that exposure to another aroma (e.g., rosemary, a relaxing odor), as well as the method used to present the aromas, affect performance on attentional blink tasks. Specifically, using a between-subjects design, we asked participants to perform the task while wearing a peppermint-, lavender-, or rosemary-scented sanitary mask (or while wearing an odorless mask under a control condition). These products, which are types of sanitary mask supposed to prevent the spread of airborne diseases, are common in Japan. If the hypothesis proposed by Colzato et al. (2014) were applicable under the experimental conditions, the attentional blink would be increased under the stimulating peppermint condition but reduced under the relaxing rosemary and lavender conditions. Interestingly, the results revealed reduced attentional blink effects under all scented-mask conditions compared with under the control condition. This pattern of results partially disconfirmed the hypothesis and suggests that an improved allocation of attention in the temporal domain does not necessarily require that testing environments include relaxing aromas. Instead, minimal exposure to relaxing and stimulating aromas via scented sanitary masks was sufficient to obtain the reduction in the attentional blink effect.

56.4039 **High level visual processing is not spared from the attentional blink**

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The attentional blink (AB) refers to impaired target identification when it follows a previous target within 500ms. The AB also reduces distractor intrusions (erroneous reports of a distractor instead of the target) from distractors that immediately precede the target. Current theories of the AB suggest that it reflects a delay in the consolidation of fully processed visual stimuli into working memory. Alternatively, the AB might reflect impaired processing of visual information. To confront these competing accounts, we manipulated the feature dimension that participants had to report (i.e., the response feature). We predicted that if perceptual processing is impaired by the blink, the AB and the accompanying reduction in pre-target distractor intrusions should be largest for the more complex response feature. Conversely, we expected no effect of the present manipulation if the AB only affects consolidation in working memory. The results of three experiments showed that when participants had to report the more complex feature (identity) the AB was larger and intrusions from pre-target distractors were less frequent, relative to when the response feature was simpler (color). We conclude that the visual processing of high level features is more susceptible to the blink disruption than the processing of low level features, which is incompatible with the popular notion that stimuli are fully processed during the blink

Acknowledgement: Israel Science Foundation Grant 1475/12 to Dominique Lamy

56.4040 **T1 visibility influences the strength of T2 attentional blink when target locations are spatially uncertain.**

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Attentional blink (AB) refers to the phenomenon where conscious report for the second target (T2) following the first target (T1), both embedded in a stream of items under rapid serial visual presentation (RSVP), becomes difficult if T2 follows no later than 500 ms after T1. The present study examined the influence of T1 visibility on T2 AB strength according to the bottleneck account, which proposes that the amount of allocated resources for T1 processing determines the strength of AB against T2. Experiment 1 used a multiple-RSVP method displaying four single-RSVP streams simultaneously at four fixed locations. T1 visibility was manipulated by lowering the luminance contrast between T1 and the gray background. In the high-visibility condition, T1 was shown in black to create a higher contrast against the gray background; whereas in the low-visibility condition, T1 was shown in dim gray to create a lower contrast against the background. Experiment 2 used the same stimuli and procedure as Experiment 1 but replaced the letter distractors with "#" signs. In both experiments, we found that T2 identification accuracy was higher in the high-visibility T1 than low-visibility T1 condition, indicating that stronger AB was present for the low-visibility T1 than the high-visibility T1. The results suggest that lowering T1 visibility exacerbated by target location uncertainty demands greater attentional resources for T1 and therefore creates a consolidation bottleneck against T2, where T2 identification suffers from a lack of resources necessary for T2 processing.

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56.4041 **Attentional blink during simulated driving**

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The attentional blink (AB) is the finding that identification of the second of two sequentially presented targets (T1, T2) is impaired if they occur within about 500ms of each other. Although hundreds of AB studies have been conducted over the last 25 years, one criticism that has been leveled at AB research is that it has no real-world applicability. In the present work, we examine the AB within the context of driving a car. Three experiments were conducted in a simulator and, in all three, impairments consistent with the AB were found. In Experiment 1, participants followed a lead vehicle and a rapid serial visual presentation (RSVP) of digits, with two letters inserted in the stream, were presented on the back of that lead vehicle. Accuracy of identification of the T2 letter showed the typical AB pattern (i.e., impairment when presented 300ms after T1, and good performance when the separation was 700ms). In Experiment 2, the RSVP contained only a single target for identification, and T2 consisted of a response to the lead vehicle braking. RTs to press the break again showed a typical AB pattern, with improved (faster) responses as the separation between the two targets increased. In Experiment 3, drivers followed a lead car on a busy expressway and were told to drive as normally as possible while following that vehicle. At random intervals the lead vehicle would apply its brakes, and again RT to initiate a braking response was measured. Critically, cars in the adjacent lanes would occasionally engage their turn signal to indicate that they wanted to make a lane change. When that turn indicator was presented shortly before the lead vehicle applied its brakes, the participants' RT was impaired. Therefore, the results of the present work suggest that the AB does have real-world applications.

Attention: Inattention, blindnesses, and awareness

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56.4042 **The spatiotemporal dynamics of perceptual grouping in motion-induced blindness** Dustin Cox[1](dcox2013@fau.edu), Sang Hong[1, 2]; [1]Department of Psychology, College of Science, Florida Atlantic University, [2]Center for Complex Systems and Brain Sciences, College of Science, Florida Atlantic University

Multiple motion-induced blindness (MIB) targets undergo visibility transitions (disappearance/reappearance) simultaneously when they can be grouped. Conversely, the visibility transitions of multiple targets occur independently when they are not easily grouped. It has been shown that multiple grouping cues can interact and differentially influence the accumulated duration of simultaneous target disappearance depending on the relative strength of each grouping cue. In the current study, we investigated the spatiotemporal relationship of the individual visibility transitions for multiple MIB targets as a function of the strengths of grouping cues. Specifically, we examined the relative timing of the disappearances/reappearances of two MIB targets as a function of their spatial proximity and feature similarity (orientation/color). Over the course of each trial, participants tracked the disappearances of two MIB targets by pressing and holding down two keys that were each assigned to one of the targets for the duration of their respective invisibility periods. The participants then released the key(s) once the corresponding target(s) reappeared. Disappearance event durations were defined as the elapsed time beginning from the moment a single target disappeared and ending once the other target disappeared when both targets were initially visible. Reappearance event durations were defined as the elapsed time beginning from the moment one target reappeared and ending once the other target reappeared when both targets were initially invisible. It was found that the mean elapsed time for multiple targets to sequentially disappear/reappear was briefer (more simultaneous) when grouping cues were strong compared to when grouping cues were weak. This result indicates that the spatiotemporal dynamics of multiple individual MIB target visibility transitions vary as a function of the strength of available grouping cues.

56.4043 **Individual differences in motion induced blindness: small-sample factor analysis of stereoscopic depth and mask coherence data reveals independent processes for frequency and duration of blindness episodes** David Peterzell[2](davidpeterzell@mac.com), Joseph LaBarre[1], John Sparrow[1]; [1]University of New Hampshire at Manchester (USA), [2]John F. Kennedy University, Pleasant Hill CA (USA)

Motion-induced blindness (MIB) occurs when a moving pattern of visual elements (mask) causes the perceived disappearance and reappearance of stationary targets. Sparrow et al. (2017, Vision Research) investigated the effects of stereoscopic depth ordering of targets relative to the mask plane (Front, Behind, Same), and motion coherence of the mask elements (0%, 50%, 100%). For each of the 3x3 conditions, both the frequency (number of blindess episodes) and duration (disappearance time) of MIB events were measured in 9 individuals. For each individual/condition, measures were obtained for sixty thirty-second presentations. Although the original study analyzed mean group differences, our reanalysis used correlations and factor analysis to examine underlying processes. Five Varimax-rotated principal components explained 96% of the total variance in a combined (frequency, duration) data set. Three factors loaded exlusively onto frequency data, including one for each of three depth conditions. One of these three factors represented an opponent process. (The three factors accounted for 93% of the variability in the frequency data alone). Two additional factors loaded exclusively onto duration of blindness episodes (accounting for 93.5% of the variability in the duration data alone). Of these, a single broad, general factor determined over 85% of the individual variability in duration. A second minor factor loaded weakly on to data for some 0% coherence mask conditions (Behind and Same depths). The three factors defining MIB frequency were clearly independent of the two defining MIB duration. Together, the results suggest that previous findings showing effects of depth order (Graf et al 2002) are explainable by processes that initiate MIB episodes, while other findings showing effects of mask coherence (Wells et al 2011) are explainable by processes that determine blindness duration and that terminate MIB episodes. Although further verification/clarification of these factors requires a much larger sample, surprisingly clear factors emerged using only 9 extensively-measured participants.

56.4044 **The Influence of Attention-Deficit/Hyperactivity Traits on Motion-Induced Blindness** Jeroen van Boxtel[1,2](j.j.a.vanboxtel@gmail.com), Cassandra McEwen[1]; [1]School of Psychological Sciences, Monash University, [2]Monash Institute of Cognitive and Clinical Neuroscience

Typically, individuals have a bias towards the left visual field. This is often absent in individuals with attention-deficit/hyperactivity disorder (ADHD). A motion-induced blindness task with four targets arranged in a square formation was used to measure left/right and upper/lower spatial biases, and changes over time-on-task. University students (41 female and 17 male) completed the Conner's Adult ADHD self-report short-form, with scores above and below the median forming high (n=30) and low (n=28) attention-deficit/hyperactivity (ADH) trait groups respectively. Both groups had left biases for the total duration of perceptual disappearances and only the high group had left biases for the total number, which all decreased over time-on-task. Group differences emerged when comparing the four spatial quadrants: only the high ADH group showed a significant bias towards the lower left visual field for the duration of disappearances. This result could be attributed to an additive effect of left/right and upper/lower spatial biases. However, no significant biases presented for either ADH group for the number of disappearance when comparing all four targets, highlighting that two independent mechanisms might govern the number and duration of disappearances in MIB. This study supports an association between spatial attention, arousal and ADH traits in MIB.

56.4045 **Change blindness for changes in 3D structure** Ellis Gootjes-Dreesbach[1](E.L.Gootjes-Dreesbach@reading.ac.uk), Peter Scarfe[1], Andrew Glennerster[1]; [1] School of Psychology and Clinical Language Sciences, University of Reading

Scarfe and Glennerster (VSS, 2016) reported low detection rates for the displacement of a single element in an otherwise stable scene. Here we report performance on the same stimuli when the target is known and compare it to the existing literature on disparity change thresholds. Unlike the detection of change when the entire scene expands (Glennerster et al, 2006), stereo algorithms using these input images would readily detect the target movement. Participants had to identify whether the target, a chequered sphere (viewing distance between 2.5 and 7.5m) presented in immersive virtual reality, moved between intervals (it did so on 50% of trials). When the target was displaced (+/- 2m or, on other runs, +/- 0.3m) it maintained its retinal size. Either 3 or 15 additional distractor spheres were presented at a similar range of viewing distances. In one condition, rods or 'dipoles' joined pairs of spheres and switched to link different pairs between intervals. This manipulation provides no additional information for feature-based stereo algorithms. We found that detection thresholds for movement overlapped with the range of thresholds reported previously (McKee, Levi & Bowne, 1990) when the target was known, but were much higher when the target was unknown. We interpret these results in terms of the number of 'channels' that the participant must monitor and hence analyse limitations on performance in relation to memory constraints rather than 3D reconstruction.

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56.4046 **Change blindness in augmented reality: Solution by monocular presentation** Akihiko Kitamura[1,2], Yasunori Kinosada[1], Kazumitsu Shinohara[1]; [1]Graduate school of human sciences, Osaka university, [2]Research Fellow of Japan Society for the Promotion of Science

Change blindness (CB) is a failure of change detection that occurs if a distractor is presented when the change occurs. In some previous studies, even though the distractor covered only some of the stimuli images, CB occurred. Therefore, augmented reality (AR), which is an emerging technology in which information is superimposed onto the real world, may lead to CB and may be dangerous in actual use. A monocular type of AR system may solve this problem. In this system, an AR image is presented monocularly. We investigated CB in a monocular AR and hypothesized that CB did not occur in the monocular condition. This is because a participant can observe the real world continuously by using the eye to which the AR image is not presented. On the other hand, in the binocular AR

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condition, CB seems to inevitably occur because previous studies revealed that CB occurs when a distractor is presented binocularly. We conducted a typical flicker paradigm CB task. An original image and a modified image were presented alternately and repeatedly without blanking until participants detected the change. The distractor was a semitransparent AR rectangle, and it was presented binocularly or monocularly. This monocular AR distractor is the most important difference compared as with previous studies, in which the distractor was presented in the real world binocularly. As we hypothesized, CB rarely occurred in the monocular condition. This result indicates that participants can choose information to detect changes in the eye to which the AR image is not presented before the information from both eyes is integrated. By contrast, in the binocular condition, CB occurred. This indicates that a monocular presentation can solve the CB in actual AR use. In order to detect a change, monocular continuous information is needed, and it does not have to be binocular.

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56.4047 Attention sets in sustained inattentional blindness are category-based

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In a sustained inattentional blindness task, people who selectively attend to one set of objects and ignore another fail to notice unexpected objects. Their likelihood of noticing is driven by similarity of the unexpected object to the attended and ignored sets, but how do we assign membership to these sets? Do we select individual object features (e.g., enhancing "black" and suppressing "white") or do we group objects into categories like "white" and "non-white?" These two accounts predict different rates of noticing for unexpected objects that share a set's category but not its member features. In a large, preregistered study (https://osf.io/7pz35), participants tracked either a set of four white shapes or a set containing four uniquely colored shapes (red, yellow, black, and purple), counting the number of times the attended items bounced off the edges of a displayed window. On the third trial, an unexpected shape passed though the display. The shape was either white, a color in the nonwhite set, or a color unique to the display but in the "nonwhite" category (green). If attention sets are category-based, green objects should be ignored along with the red, black, purple, and yellow objects because they too fall into the "non-white" category. Consistent with this prediction, when ignoring the nonwhite shapes, participants noticed the green unexpected object no more often than one exactly matching an ignored color, and when attending to the nonwhite shapes, participants were just as likely to notice a green shape as one with an attended color. In this task, attention sets were based on broader object categories rather than individual object features. Noticing of an unexpected object depends on which category it belongs to, and not merely how similar its features are to the attended and ignored sets.

56.4048 The unnoticed zoo: inattentional deafness of animal sounds in music

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Inattentional unawareness potentially occurs in several different sensory domains, but is mainly described in visual paradigms ("inattentional blindness", e.g., Simons & Chabris, 1999). Dalton and Fraenkel (2012) were the first to show that a clearly noticeable odd auditory stimulus can be presented without getting detected at all, thus also revealing the susceptibility to "inattentional deafness". Participants were instructed to listen binaurally to a conversation. In the middle of the presentation, a voice repeatedly said "I'm a gorilla". Although the auditory gorilla was clearly noticeable if participants paid attention, it was missed by 70% when they were focusing on the conversation. The present study investigated influences on the susceptibility to this phenomenon and extended the paradigm by using 10 excerpts of musical pieces which were modified by adding different animal sounds. Participants' task was to count varying musical features (e.g., drum beats). Furthermore, data on musical expertise, attentional focus, motivation to succeed at the counting task, and differences in musical pieces and counting tasks (feature similarity & perceptual load) were collected. Results showed that the frequency of missed animal sounds was higher in participants with higher attentional focus and motivation. All other factors did not have an influence on detecting or missing animal sounds. We could demonstrate inattentional deafness in music for highly salient and odd auditory sounds such as animal sounds and in some participants a consistent susceptibility across several musical pieces.

56.4049 Sad minds seeking happy stimuli: Trait happiness predicts how quickly happy faces reach visual awareness

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The light entering the eyes conveys far more information than can possibly be promoted into visual awareness in any given moment, and so vision is inherently selective. We have learned a great deal about this selection in recent years, especially about the factors that influence whether (and how quickly) we are likely to consciously perceive various sorts of stimuli. At the same time, however, we know much less about how patterns of unconscious, automatic selection may differ across people. Here we explored such individual differences in the context of an especially salient aspect of our lives: trait happiness. People differ widely in how happy they generally are (beyond their temporary state moods), and we asked about whether this factor might interact with how quickly happy vs. unhappy information reaches visual awareness. We showed people happy, sad, fearful, and neutral faces that were rendered invisible using continuous flash suppression (CFS), and then we measured how quickly such faces broke through CFS into awareness. Several different subsequent measures of trait happiness and life satisfaction (but not measures of state mood) were reliably correlated with performance: the less happy observers were (controlling for state mood), the faster they became aware of happy faces (using neutral faces as a baseline). Critically, this pattern occurred only for happy faces, and not sad or fearful faces — and a monocular control experiment ruled out response-based explanations that did not involve visual awareness, per se. People who are less happy may thus automatically and unconsciously prioritize happy stimuli, perhaps because of the ability of those stimuli to modulate their emotional experience. In this way, people who are differentially happy may literally experience different visual worlds even when in the same environment — such that the study of perception may contribute to affective science.

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56.4050 Going to the movies: Immersion, visual awareness, and memory.

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Immersion describes the extent to which an observer feels involved in a virtual experience. In immersive environments, observers report high levels of sensory interaction, story engagement, and an impression of reality. Does immersion affect perceptual and cognitive performance? The current experiment examined the effect of immersive environments on inattentional blindness-like (IB-like) phenomena and memory. To that end, we used two model theaters to manipulate observers' sense of being immersed. The realistic condition used a scaled down model of a realistic movie theater (complete with patrons), and the haphazard condition used a model with the same dimensions, but materials were haphazardly placed around so as not to resemble an actual theater. Participants ($N = 31$) watched the first 10 minutes of a movie. Five minutes into the movie, a computer-controlled motor moved an unexpected stimulus (either a model movie patron or a bolt) across the stage area of the model. Upon completion of the clip, participants were first asked if they noticed the unexpected object as an IB-like measure (IB-like since it's possible people saw, and then forgot, the unexpected object). Immersion was then measured using Jennett et al.'s (2008; International Journal of Human Computer Studies) questionnaire, and memory was assessed with a 10-question multiple-choice test about the movie clip. The results from the immersion questionnaire replicated previous research: the realistic model induced higher levels ($M = 5.68$) of immersion than the haphazard model ($M = 5.05$; $p < .05$). However, IB was about the same in both conditions (realistic: 22.2%, haphazard: 23%). Memory test accuracy was similar for both conditions too (realistic $M = 89.23\%$; haphazard $M = 89.44\%$). These results suggest that environments designed to induce immersion may do so successfully without having large effects on performance measures like memory

Binocular Vision: Rivalry and bistability

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56.4051 The onset bias of bi-stable perception across the horizontal and vertical meridians

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The initial dominance of bi-stable perception has a stable and local bias that vary across the visual field. The neural mechanism for this local onset bias remains unknown. In this study, we investigated the relationship between the onset biases of two spatially adjacent locations, either in the same quadrant, or across the horizontal or vertical meridians. Stimuli presented across the vertical meridian project to different hemispheres, while cortical representations across the horizontal meridian are separated at V2 and beyond. For each subject, in multiple sessions from different days, we measured the initial dominance of binocular rivalry and monocular ambiguous structure-from-motion (SFM) stimuli at 24 locations across the visual field. These locations were arranged on a circle at an eccentricity of 7.7 degrees, and equally separated by 2 degrees of visual angle. For both binocular rivalry and SFM stimuli, the initial dominance at each location showed a stable perceptual bias across different days. We then evaluated the correlation of the onset biases from adjacent spatial locations. The onset bias of binocular rivalry was similar between two adjacent locations in the same quadrant or across the horizontal meridian. However, the perceptual bias became independent between locations across the vertical meridian. For the SFM stimuli, the perceptual bias was highly correlated between adjacent spatial locations, no meridian effect was found. Our data suggest that the long term onset bias of binocular rivalry might has a neural substrate in the early retinotopic visual cortex (likely V1).

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56.4052 The Modularity of Brain Dynamics: Insights from Bistable Perception

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In bistable perception, constant input leads to alternating perception. The dynamics of the changing perception reflects the intrinsic dynamic properties of the 'unconscious inferential' process in the brain. Under the same condition, individuals differ in how fast they experience the perceptual alternation. In this study, testing many forms of bistable perception in a large number of observers, we investigated the key question of whether there is a general mechanism or multiple modular mechanisms that control the dynamics of the inferential brain. Bistable phenomena tested include binocular rivalry, vase-face, Necker cube, moving plaid, motion induced blindness, biological motion, spinning dancer, rotating cylinder, lissajous-figur, rolling wheel, and translating diamond. Switching dynamics for each bistable percept was measured in 100 observers. Results show that the switching rates of subsets of bistable percept are highly correlated. Further control experiments show that the correlations among subsets of bistable phenomena were not due to correlated eye movement or blink. The clustering of dynamic properties of some bistable phenomena but not an overall general control of switching dynamics implies that there the brain's inferential processes are modular – faster in constructing 3D structure from motion does not mean faster in integrating components into an objects.

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56.4053 Continuous flash suppression is strongest for low temporal frequencies, high spatial frequencies and iso-oriented targets

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Continuous flash suppression (CFS) is a psychophysical technique where a rapidly flickering Mondrian pattern viewed by one eye suppresses the target in the other eye for several seconds. Despite the widespread use of CFS to study unconscious visual processes, the temporal tuning of CFS suppression is unknown yet is thought to require high temporal frequencies. We used spatiotemporal filtering of dynamic noise patterns to produce narrow-band masking stimuli which were used to probe the temporal, spatial and orientation characteristics of CFS. Surprisingly, CFS suppression with narrowband stimuli peaks very prominently at approximately 1 Hz, well below the rates typically used in CFS studies (10 Hz or more). As these studies generally use a flickering Mondrian pattern – a broad-band stimulus – our finding shows it is the low-frequency component of the Mondrian that is responsible for most of the suppression. As well as being strongly low-temporal-frequency biased, CFS suppression is greater for high spatial frequencies and for increasing masker contrast. Selectivity for low temporal and high spatial frequencies, and a rising monotonic contrast function, suggest parvocellular/ventral mechanisms underlie CFS suppression. These results are similar to findings in binocular rivalry, and thus unify two phenomenon previously thought to require different explanations. While high temporal frequency maskers can induce CFS suppression, it is much weaker – whether measured in target suppression duration or target contrast threshold elevation. Using orientation filtering, we found another difference between low- and high-temporal frequency CFS suppression: at low frequencies, CFS suppression is strongly orientation tuned while at high frequencies orientation selectivity is much weaker.

56.4054 Audio-visual Interactions in Multistable Perception: Evidence from No-report Paradigms

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Multistable phenomena are observed for almost any sensory modality, yet studies on multisensory interactions in multistability are surprisingly rare. Typically, such studies address the consistency of statistical properties and individual biases of multistability across modalities, or one modality is used to distract attention from the other. Very few studies attempt to measure multistability in two modalities simultaneously. This might be a consequence of the difficulty to query two modalities simultaneously without response interference or dual-task costs. We overcome this issue by using no-report paradigms for the visual modality. Specifically, we continuously read-off the perceptually dominant direction of motion from the slow phase of the optokinetic nystagmus. We present three studies that use this no-report approach to probe audio-visual effects. The first study demonstrates that newly learnt audio-visual associations bias subsequent binocular rivalry: a grating previously coupled with a concurrently presented tone dominates over a grating previously coupled with a different tone. The second study uses binocular rivalry to tag the dominant percept in auditory multistability: two distinct tone sequences are simultaneously presented; a grating that has motion transients co-occurring with the tone perceived in the foreground dominates over a grating whose motion transients co-occur with the competing background tone. Third, a dynamic visual stimulus that is alternatingly perceived as plaid or two gratings, is presented simultaneously with a multistable auditory stimulus. Despite some evidence for intra-observer consistency between the two modalities, we find little influence of the reported auditory percept on the concurrently measured visual percept. Hence, situations in which auditory perception affects visual rivalry can readily be created, through stimulus design or by learnt associations, but configurations exist where the cross-modal influence is minimal. Our results make a case for no-report paradigms as a useful tool to study truly multimodal effects in multistability.

56.4055 The influence of associative learning on perceptual decisions in ambiguity

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Expectations about the sensory environment have a strong impact on perceptual decisions. However, the computational and neural mechanisms by which perceptual expectations are updated, maintained and used for visual perception remain poorly understood. In this model-based fMRI experiment on 15 healthy participants, we used an associative learning task to elicit changing expectations about the appearance of ambiguous stimuli. Conventional analyses revealed that perceptual decisions under ambiguous viewing conditions were biased by perceptual history and learned associations. In a computational modeling approach, we showed that participants' behaviour was best explained by a hierarchical Bayesian model incorporating continuously updated priors from previous perceptual decisions and associative learning. Model trajectories for predictions and predictions errors correlated with BOLD-activity in orbitofrontal gyrus and inferior frontal gyrus, respectively. Effective connectivity analyses using Dynamic Causal Modeling indicated a relevant impact of such regions on activity in sensory cortices via feed-back connections. Our results suggest that visual perception is informed by different sources of prior expectations, which are updated by Bayesian learning and used to infer on the causes of sensory stimulation in a continuously changing environment.

56.4056 **Visual working memory affects the perception of ambiguous SFM (structure-from-motion) by enhance internally directed attention** Jingjie Li[1,2](jingjie.li@stu.xjtu.edu.cn), Hao Wu[1], Badong Chen[1]; [1]School of Electronic and Information Engineering, Xi'an Jiaotong University, [2]School of Life Science, Xi'an Jiaotong University

Previous studies show that an unambiguous prior stimulus can cause an ambiguous stimulus to be perceived in the same way, which we usually call the perceptual memory. Holding the unambiguous stimulus in visual working memory could strengthen this effect. Here we hypothesize that the prior unambiguous SFM can evoke internally directed attention and affect the representation of the coming up ambiguous SFM, and holding it into visual working memory could enhance this effect. To test this hypothesis, we carry out two behavior experiments. In the first experiment, subjects are asked to watch a serial of unambiguous SFM-delay-ambiguous SFM with two tasks, one for attending only and one for holding the rotation speed of the unambiguous SFM into the working memory. This experiment shows that the working memory task could strengthen the perceptual memory of unambiguous SFM significantly ($p< 0.01$). In the second experiment, the subjects watch a serial of unambiguous SFM- delay- unambiguous SFM stimulus and perform an Stroop-like RT task. The rotation direction of the second SFM may be congruent or incongruent with the first SFM. The normalized difference of this contrast get larger when subjects performing a WM task ($p< 0.01$). Furthermore, we find that this RT difference can predict the perceptual memory performance in each task across subjects($r=0.48$, $p< 0.05$), revealing a direct link between internally directed attention and the perception bias. Our results demonstrate that the working memory task could improve the perceptual memory performance via enhancing the internally directed attention, and the internally directed attention is strongly correlated with the perceptual memory phenomenon.

Acknowledgement: 973 Program (No. 2015CB351703)

56.4057 **Bolstering inter-observer differences to study the mechanisms behind perceptual bistability** Jan Brascamp[1](brascamp@msu.edu), Mark Becker[1], David Hambrick[1]; [1]Department of Psychology, Michigan State University

Individuals systematically differ in the rate of perceptual changes when viewing ambiguous or conflicting visual stimuli. Some observers report more frequent changes, and may be called 'fast switchers'; others are 'slow switchers'. Previous research suggests that these individual differences during perceptual bistability could be related to differences in sensory adaptation and/or attentional processes. Here we investigate these possibilities by determining whether inter-observer variability in switch rate correlates with inter-observer differences on tasks designed to tap these two putative mechanisms. As a first step we verified that perceptual switch rate within an individual is stable across bistability paradigms, a possibility drawn into question by recent work1. We observe robust correlations, in terms of the number of switches per unit time, among binocular rivalry, ambiguous structure-from-motion and motion-induced blindness. This points to a common factor behind the perceptual cycle, regardless of specific paradigm. We then selected three paradigms designed to index sensory adaptation, namely motion aftereffect, tilt aftereffect, and negative afterimage paradigms. The dependent variable for each was aftereffect strength: a putative index of the degree of sensory adaptation. Similarly, to gauge attention function we selected a triplet of paradigms that included a Stroop task, a visual search task and an antisaccade task, each with reaction time as the index of attentional control. Preliminary results show significant correlations among the three 'attention' paradigms, and trends toward significance for the 'adaptation' paradigms, suggesting that each triplet of tasks does index a single underlying variable. We are currently collecting additional data with the ultimate goal of performing a latent variable analysis to probe the relationship between these putative cognitive mechanisms and perceptual shift rate. However this latent analysis comes out, the results will provide empirical constraints on theories about the mechanisms of perceptual bistability. 1. Gallagher, R. M., & Arnold, D. H. (2014). Perception, 43(11).

56.4058 **Interocular Grouping During Binocular Rivalry in Younger and Older Adults** Amanda Beers[1](beersam@mcmaster.ca), Allison Sekuler[1], Patrick Bennett[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Binocular rivalry typically is discussed in terms of competition between the eyes. However, pattern coherency also has been suggested to drive rivalry. Whereas different patterns are presented to each eye in the classic rivalry paradigm, Kovacs and colleagues (1996) tested the pattern coherency hypothesis using patchworks of two patterns in which complementary pattern sections were presented to each eye. Reports of coherent pattern ("exclusive") percepts during this patchwork condition, which require interocular grouping, have been cited as evidence for stimulus-based rivalry. Here, we examine aging effects on interocular grouping, and thus stimulus-based rivalry. In each of two experiments, we presented two distinct patterns (concentric rings and diagonal lines) in intermixed trials of the classic and patchwork rivalry paradigms. On each trial, the contrast of the two patterns was either equal or differed significantly (0.6). During classic trials, each eye was shown the same pattern throughout Experiment 1; Experiment 2 counter-balanced the pattern shown to each eye. Eight younger (aged 20-28) and eight older (aged 71-77) observers participated in Experiment 1, and a different set of eight younger (aged 19-26) and eight older (aged 72-77) observers participated in Experiment 2. For the duration of each trial (Experiment 1: 40 s; Experiment 2: 30 s), participants used a handheld button box to classify percepts into three categories: two exclusive (rings or lines) or mixed. Overall, exclusive percepts were reported a significantly greater proportion of time during the classic than patchwork trials. Introducing a difference between the contrast levels of the two patterns increased the monocular and pattern dominance respectively for classic and patchwork trials. Interestingly, there was little evidence of significant age-related changes in the proportion of exclusive percepts or dominance in either paradigm, unlike previous findings for the classic paradigm using less complex stimuli (Beers et al., VSS 2013, 2014).

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56.4059 **On vs. off-object probes produce differential ERPs and reversal latencies in binocular rivalry** Brian Metzger[1,2](bmetzge2@illinois.edu), Kathy Low[2], Ed Maclin[2], Monica Fabiani[1,2], Gabriele Gratton[1,2], Beck Diane[1,2]; [1]Department of Psychology, University of Illinois at Urbana-Champaign, [2]Beckman Institute for Advanced Science and Technology

Binocular rivalry occurs when two highly incompatible images are presented simultaneously but separately to each eye. Rather than settle on one image, perception alternates between the two. Prior research has shown that briefly-presented probes modulate perception such that dominant-eye probes decrease the likelihood of a reversal while suppressed-eye probes increase reversal likelihood (measured as reversal latency from probe onset). We have previously shown that probe modulation varies as a function of whether probes appear on vs. off rivalry objects. Specifically, relative to off-object probes, on-object probes increase reversal likelihood when they appear in the suppressed-eye, and decrease reversal likelihood when they appear in the dominant eye. This suggests that probes boost activity for the object over which they appear, perhaps by drawing attention to that image. Here, we use ERPs to better understand why on-object probes more effectively modulate perception, separately as a function of whether probes appear in the suppressed or dominant eye. We replicate prior behavioral work showing that on-object probes modulate perception more effectively, increasing reversal likelihood for on-object suppressed-eye probes while reducing reversal likelihood for on-object dominant-eye probes. Critically, however, we show that on- vs. off-object probes significantly differ in N2 and P3b ERP activity, both of which have been implicated in higher-order attention-related processes. Relative to off-object probes, on-object probes presented to the suppressed-eye elicit increased N2 activity followed by increased P3b activity. Relative to off-object-probes, on-object probes presented to the dominant-eye also elicit increased N2 activity, but are not followed by increased P3b activity. The data suggest that suppressed-eye on-object probes draw attention (as indexed by N2 amplitude time-locked to probe onset) to the object over which they appear, thereby increasing the likelihood of a perceptual reversal.

Acknowledgement: NIH R01EY022605

56.4060 **Dissimilarity between feature ensembles triggers binocular rivalry without competing local features** Oakyoon Cha[1](oakyoon@gmail.com), Randolph Blake[2], Sang Chul Chong[1,3]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology and Vanderbilt Vision Research Center, Vanderbilt University, [3]Department of Psychology, Yonsei University

Viewing the world with both eyes open, our visual experience belies no hint of its dual origins, because the two monocular images are virtually identical in terms of their feature content, with only the slight perspective differences affording a somewhat enhanced sense of three-dimensionality. Vision's dual origins are dramatically revealed, however, when the two eyes view dissimilar monocular stimuli: stable single vision gives way to alternating perceptual dominance between the two distinct monocular views (binocular rivalry). We have investigated the extent to which similarity between feature ensembles, but not object-to-object matches, govern whether one experiences binocular fusion or binocular rivalry. We created two sets of novel, dichoptically viewed stimuli that comprised numerous simple shapes, none of which were imaged on corresponding retinal locations. We predicted that two sets would form an integrated, stable binocular impression when the pair of feature ensembles viewed by the two eyes were the same, but would trigger binocular rivalry when feature ensembles were different between the two eyes. We used a probe technique to test those predictions. During extended viewing, brief presentations of one or two dots (probes) occurred irregularly, and participants reported when such events were detected and how many dots were seen. Probes were always imaged separately in each eye when two probes were presented. The probability of missing one of two probes should be higher if one of the two sets was suppressed as a result of ongoing binocular rivalry. Results showed that indeed participants were more likely to fail seeing one of two probes when the feature ensembles were different. Thus, our results suggest that feature ensembles can sway binocular perception in favor of fusion or rivalry depending on ensemble similarity across the two eyes.

Acknowledgement: This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (NRF-2016R1A2B4016171).

56.4061 **Exploration of Interocular Suppression Using Perceptual Reverse Correlation and Computational Modeling** David Nichols[1](dnichols@roanoke.edu), Stephanie Shields[1]; [1]Department of Psychology, Roanoke College

Binocular rivalry is often studied with participants making perceptual reports about which of two overlapping incongruent images presented to different eyes, such as rivalrous gratings, are visible at any particular moment in time. However, the rivalrous gratings being judged are also directly activating the neural mechanisms involved in the perceptual decision process, i.e. interocular suppression. Taking advantage of the spatially extended nature of interocular suppression with a continuation of a combined psychophysical and computational modeling study (Nichols & Wilson, 2009), the current study temporally modulated the presence of surround annuli while participants made judgments on the visibility of static circular gratings that were presented to either one eye (monocular) or both eyes with different orientations (rivalrous). A perceptual reverse correlation technique was used with moving gratings in the surround annuli changing direction every second while also randomly changing with regard to which eye or eyes they were presented to. Key qualitative findings were replicated, e.g. the presence of an annulus in the eye contralateral to a monocular center grating is necessary for the suppression of the grating but removal of the annulus is not necessary for the reappearance of the grating. New qualitative findings included how the presence of an ipsilateral annulus is similarly influential for the return to perceptual dominance for both monocular and rivalrous center gratings. New quantitative measurements included the relative necessity and sufficiency of different annulus conditions for interocular suppression. Implementation of the model with fluctuations in the input strength of the surround components that inhibit the center components to match the experimental design revealed many qualitative similarities to the data but also some qualitative and quantitative differences. Future tuning of the model to establish greater consistency with the psychophysical data can shed light on the role of contralateral and ipsilateral surrounds in interocular suppression.

OBJECT RECOGNITION: CATEGORIES

Tuesday, May 23, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4062 **Are all visual objects created equal?** Marlene Behrmann[1](behrmann@cnbc.cmu.edu), Jacob Geskin[1]; [1]Department of Psychology, Carnegie Mellon University

Are segregated and independent psychological and neural mechanisms required for the recognition of different visual inputs such as faces and common objects? One source of evidence to address this question comes from studying associations versus dissociations of function in individuals with impairments in visual recognition. Here, we examine whether an impairment in face recognition is accompanied by a deficit in object recognition in individuals with congenital prosopagnosia (CP), an apparently lifelong problem that occurs without brain damage (on conventional MRI) and with normal vision and intellect. We present survey data from an analysis of 712 cases of adults with CP dating from 1976 to the present time (117 papers) and of 42 cases of children with CP. Of those reports where there are sufficient data to adjudicate this issue (i.e. testing of both faces and object perception completed and adequate dependent measures), 91.7% of CP individuals have both prosopagnosia and visual object agnosia, either mild (26.4%) or more severe (65.3%). The remaining 8.3% of individuals do not have an obvious object recognition deficit. We propose a single mechanism account that may explain both the preponderance of associations and the small set of dissociations within the context of a single mechanism, and we offer suggestions for research that would permit further evaluation of the relationship between object agnosia and prosopagnosia.

Acknowledgement: National Science Foundation

56.4063 **Context Modulation of Ambiguous Object Perception in The Absence of Awareness** Dan Biderman[1](danbider@gmail.com), Liad Mudrik[1,2]; [1]School of Psychological Sciences, Tel Aviv University, Tel Aviv, Israel , [2]Sagol School for Neuroscience, Tel Aviv University, Tel Aviv, Israel

Visual perception is continuously shaped by both bottom-up and top-down information. A classic example for top-down modulation is the influence of context on the perception of an ambiguous stimulus: the latter can appear as an utterly different object when it is embedded in different contexts. Can such contextual effects on perception occur even when the context is not consciously perceived? While some low-level contextual effects (brightness and tilt illusions) were found even without awareness of the inducing context, high-level visual illusions (namely, perceiving Kanizsa shapes) were not. Here, we investigated this question using non-illusory, higher-level stimuli, while also manipulating the physical properties of the critical ambiguous stimulus. Observers were presented with six versions of the well-known B/13 ambiguous stimulus. These versions varied in distance between the two parts of the stimulus, hereby making it more similar to B or to 13. This ambiguous stimulus was presented for 33 ms together with context inducers which were either letters ("A" and "C") or numbers ("12" and "14"). While the ambiguous stimulus was always visible, the context inducers were sandwich masked. In Experiment 1 (conscious; N=12), 100 ms blanks were introduced between the context inducers and the masks, so the inducers were visible. In Experiment 2 (unconscious; N =24), the order of masks and blanks was switched, rendering the inducers invisible. Subjects' awareness of the inducers was assessed using the Perceptual Awareness Scale and an additional objective visibility test in which observers judged whether the inducers were letters or numbers. Experiment 1 revealed both

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context and distance effects (all ps< 0.01). Crucially, this pattern was also observed in Experiment 2 (all ps< 0.01), demonstrating that subjects' interpretation of an ambiguous stimulus can be biased by the context in which it appears, even when this context is not consciously perceived.

Acknowledgement: Israel Science Foundation

56.4064 Investigating contextual effects in the Vanderbilt Holistic Processing Task Ting-Yun Chang[1](ting-yun.chang@vanderbilt.edu), Isabel Gauthier[1]; [1]Department of Psychology, Vanderbilt University

Context can influence measures of holistic processing for non-face objects in the composite matching task, in which observers match object parts in a sequential matching task, while ignoring other parts. In one study, observers were more influenced by the congruency of irrelevant parts for novel objects when parts of the study object were sometimes misaligned, influencing even the trials on which the study parts were aligned. Other work found that novel objects were processed more holistically when a face was held in working memory. A new version of the composite paradigm, using 3-AFC trials, was recently created to provide reliable measurement of individual differences in holistic processing (Richler, Floyd, & Gauthier, 2015). In this paradigm, we examined whether holistic processing for novel objects processed by novices is sensitive to context. In Experiment 1 (n=89), we measured holistic processing for novel objects in the context of other trials in which study objects were misaligned vs. aligned. We found no evidence that context influenced holistic processing. In Experiment 2, we examined holistic processing for novel objects under three different conditions (n=149): (1) no context, (2) among face trials, or (3) among trials for another novel object category. We expected no holistic processing under Conditions 1 and 3 because the observers had no experience with these novel objects, but that aligned faces might induce holistic processing for novel objects in Condition 2. As in Experiment 1, but unlike prior results in the standard composite task, holistic processing was not influenced by context. Despite relatively large samples, we found no evidence of contextual influences on holistic processing in the VHPT. Context could have a larger influence under conditions with more uncertainty at encoding (e.g., when subjects do not know which part of the study object will be relevant on a given trial).

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56.4065 Inversion effects in the ability to classify mammograms in one second. Michael Chin[1](michaelchin45@gmail.com), Karla Evans[2], Jeremy Wolfe[3], Jon Bowen[1], James Tanaka[1]; [1]University of Victoria, [2]University of York, [3]Harvard Medical School

One hallmark of a perceptual expert is an ability to make fast, accurate decisions. People, as face experts, can detect facial expression in less than a second. Similarly, a radiologist, skilled in detecting breast cancer, can classify mammograms as normal or abnormal at above chance levels in less than a second. The visual strategies mediating fast gist perception by radiologists are not well understood. In this experiment, we asked if radiologists were subject to the inversion effect that makes face analysis much harder if the faces are inverted. Stimuli consisted of upright and inverted bilateral mammograms displayed in a mediolateral oblique or craniocaudal view. Half of the images were "normal" and half of the images contained subtle signs of breast cancer (subtle masses or "architectural distortion"). Upright and inverted faces were used as comparison stimuli. The mammogram and face stimulus were presented for 1000ms and 250ms, respectively. For mammograms, participants were instructed to decide whether the mammogram appeared "normal" or "abnormal". For the faces, participants assessed whether the face appeared to show a "happy" or "neutral" expression. 20 radiologists were tested. Results for faces showed the expected face inversion effect where discrimination of upright faces was superior to inverted faces. Mammograms seem to show an interaction between radiology experience and orientation. Whereas the 8 less experienced radiologists (< 5 years of experience) failed to show a reliable inversion effect, the 11 more experienced radiologists (> 5 years of experience) performed more accurately with upright mammograms ($t(10) = -2.8$, $p < 0.02$). Thus, there does appear to be an inversion effect in expert mammography. The apparent effect of experiment may indicate a processing switch towards a more holistic strategy with experience, however, this hypothesis requires further testing.

Acknowledgement: The Natural Sciences and Engineering Research Council of Canada (NSERC)

56.4066 Transformation of spatial reference frame in the absence of awareness Yijun Ge[1,2](geyijun827@gmail.com), Sheng He[1,2]; [1]Department of Psychology, University of Minnesota, Minneapolis, Minnesota, United States of America, [2]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, Beijing, China

Despite the continuous movements of our eyes and body, our visual world remains stable. Key to this visual stability is the transformation of visual objects from the retinotopic to spatiotopic reference frame. Does this transformation require awareness of the target visual objects? We addressed this question using an adaptation paradigm, with the test stimulus presented either at the same retinotopic or spatiotopic location as the adapting stimulus. The logic is that if an aftereffect could be observed at the spatiotopic location, then it would imply that the adapting stimulus had undergone retinotopic to spatiotopic transformation. We first identified stimuli that are capable of generating spatiotopic aftereffects, and then the key manipulation is to render the adapting stimulus invisible (using continuous flash suppression) and investigate whether the spatiotopic aftereffects could still be observed. Two forms of visual aftereffects were employed in this study: the Tilt Aftereffect (TAE) and Face Gender Aftereffect (FGAE). First we demonstrated that both aftereffects could be induced when the test stimulus was at the same spatiotopic but different retinotopic location as the adapting stimulus, suggesting that the representation of the adapting stimulus underwent the retinotopic to spatiotopic transformation. Critically, when the adapting stimulus was rendered invisible, the TAE could only be observed at the retinotopic location but no longer at the spatiotopic location; however, the FGAE was still robust at the spatiotopic location. Thus our results suggest that, in the absence of awareness, the transformation from retinotopic reference frame to spatiotopic reference frame is stimulus dependent: face information could be transformed to spatiotopic reference frame without awareness while local orientation representation remain specific to its retinotopic location.

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56.4067 Category-selective attention for animals: Beyond visual features Chenxi He[1](ch137@nyu.edu), Olivia Cheung[1]; [1]Objects and Knowledge Laboratory, New York University Abu Dhabi

Previous studies have demonstrated that humans have an attentional priority for detecting animals compared to inanimate objects. While these findings are consistent with the claim regarding the evolutionary significance of animals in human history, it is unclear whether the attentional advantage for animals depends on visual or semantic differences between the categories. Indeed, animals and inanimate objects vary greatly in shapes, and the visual and semantic features are often confounded. To distinguish visual and semantic influences on the attentional priority for animals, we conducted two visual search experiments (both N=28). Participants searched for the presence of either an animal or a man-made object on a 6-item display, with a non-target category item (e.g., man-made object when searching for an animal) appearing as a distractor in half of the trials. The rest of the distractors were fruits/vegetables. Experiment 1 used images that differ in visual characteristics across the three categories, and revealed faster and better search for animals, compared to man-made objects, replicating previous findings. Also, search performance for either category was comparably reduced with the presence, compared to the absence, of a non-target category item. Experiment 2 used instead images that were equated in image statistics and shapes (either round or elongated) across the three categories. Two aspects of the results are critical: 1) the overall advantage for animal search, compared to object search, was minimized, but 2) an interaction in response times revealed that the presence of an animal as a non-target category distractor slowed down the search performance for object search, whereas the presence of an object distractor did not slow down animal search. These results suggest that while differences in visual features between animate and inanimate categories indeed contribute greatly to the attentional advantage for animals, part of the advantage may also be driven by semantic influences.

56.4068 **Assessing the role of task demands on object recognition under naturalistic conditions using a virtual-reality paradigm** Mohammed Islam[1](mislam19@fau.edu), Steven Oliveira[1], Elan Barenholtz[1]; [1]Psychology, Florida Atlantic University

Previous studies have demonstrated that rapid identification of objects may produce errors in object recognition. However, such studies often utilize a paradigm in which a static 2D image is briefly presented. This may limit the generalizability of the findings to the real world where other factors are likely to contribute to misidentification. In particular, under typical ecological conditions, additional task demands are likely to lead to insufficient perceptual processing, potentially leading to recognition errors. In the current study, we aimed to address this using virtual-reality to generate an ecologically valid paradigm in which we could study realistic constraints that may lead to misperceptions of real-world objects; specifically, attentional load and task demand. We immersed participants in front of an artificial conveyor-belt in a virtual environment that mimicked a toy factory. Participants were tasked to quickly categorize sets of objects into one of three bins (two which were active categories, the third being a discard bin) with their "hands." The sets of objects were accompanied by target objects. The target object appeared similar to one category, but belonged to another. The bin in which target objects were placed in were indicative of the participant's identification of the object. We manipulated the number of objects on the conveyor belt in order to increase attentional load and task demand. We found that the number of miscategorizations increased with increased task demands, suggesting that higher attentional load forces participants to rely more heavily on top-down expectations rather and perceptual processing. We conclude that real-world task demands can lead to recognition errors. More generally, these results demonstrate that virtual-reality can provide a more ecologically valid avenue for perceptual research.

56.4069 **Congruent Familiar Size Relationships Decrease Size Contrast Illusion** Margarita Maltseva[1,2](mmaltsev@uwo.ca), Kevin Stubbs[2], Melvyn Goodale[1,2], Jody Culham[1,2]; [1]Department of Psychology, University of Western Ontario, [2]Brain and Mind Institute, University of Western Ontario

Familiar size is an important cue to size and distance perception. For example, the perceived size of a car stays constant regardless of how far away it is. Relative size is also an important cue, as demonstrated by the size contrast effect in the Ebbinghaus illusion. But what happens when familiar and relative sizes conflict? Will our expectation of familiar sizes in the real world affect how we perceive size? Moreover, given that familiar size is an important organizational principle in the ventral visual stream for inanimate but not for animate objects (Konkle & Caramazza, 2013, J Neurosci), does the influence of familiar size depend on animacy? Participants judged the size of a central stimulus in the Ebbinghaus illusion, where the surrounding stimuli were physically larger or smaller than the central stimulus. The central stimulus was an animate or an inanimate stimulus of medium familiar size (Dalmatian dog or armchair, respectively) surrounded by other stimuli of smaller or larger familiar size that were animate (cats or horses) or inanimate (shoes or cars). For both the animate (dog) and inanimate (armchair) central images, perceived size was more affected by size congruency for inanimate than animate surrounds. Specifically, the size contrast illusion was strongest for incongruent size relationships with inanimate objects (e.g., a dog surrounded by small cars was perceived as considerably larger than a dog surrounded by large shoes) and weakest for congruent size relationships with inanimate objects (e.g., a dog surrounded by large cars was perceived as a similar size to a dog surrounded by small shoes). The results show that inanimate objects are more influential benchmarks for size perception than animate objects. Moreover, they show that differences between inanimate and animate stimuli in the organization of the ventral stream are reflected in behavioral size perception.

Acknowledgement: NSERC

56.4070 **Functional readout analysis reveals nonlinear representational transformation from early visual to category-selective regions** Marieke Mur[1](marieke.mur@mrc-cbu.cam.ac.uk), Judith Borowski[1], Nikolaus Kriegeskorte[1]; [1]MRC Cognition and Brain Sciences United, Cambridge, UK

Category-selective regions in human visual cortex respond strongly to objects from their preferred category and weakly to objects from non-preferred categories, with a step-like drop in activation at the category boundary (Mur et al. 2012). This categorical response profile across object images is absent in early visual cortex (EVC). How does the brain transform the low-level visual image representation into a high-level categorical object representation? The appearance of a category step suggests a nonlinear transformation. However, objects from different categories also differ markedly in low-level visual properties. If images clustered by category in the EVC representation, a linear transformation might suffice to explain the step in the activation profile of category-selective regions. Can linear readout of the EVC representation explain the activation profile of category-selective regions? fMRI data were acquired in four subjects viewing 96 colored images from multiple categories, including faces and places. We computed the activation profile across images for the fusiform face area (FFA) and the parahippocampal place area (PPA), and for each EVC voxel (Fig. 1A). We used regularized (L1, L2) linear regression to weight the EVC voxel responses, so as to best predict the activation profiles of FFA and PPA. Model performance was evaluated on a hold-out set of images not used for fitting. Our results indicate that linear readout of the EVC representation does not fully explain responses in category-selective regions (Fig. 1B). Adding a category-step predictor explained significant additional variance, especially in PPA. Correlated fluctuations between EVC and category-selective regions that are unrelated to the stimuli contributed significantly to the explanatory power of EVC, especially for FFA as target. These results indicate that functional readout of EVC by category-selective regions is nonlinear, and that differences in lower-level visual properties between categories are insufficient to explain FFA and PPA responses.

Acknowledgement: British Academy, Medical Research Council, Amgen Scholars Programme

56.4071 **Categorization specificity and sematic content impact the deployment of spatial attention** Birken Noesen[1](noesen.2@wright.edu), Assaf Harel[1]; [1]Department of Psychology, College of Science and Mathematics, Wright State University

The present study tests the interaction between object knowledge and visual attention by examining whether categorizing stimuli at different levels of specificity will affect how attention is deployed in space. In order to test for this potential interaction, we developed a new experimental paradigm, the category cueing paradigm, which combines a classic cueing paradigm with a category verification paradigm. Participants were presented with a lateralized cue label that was either at the basic ("dolphin") or subordinate ("bottlenose dolphin") categorization levels followed by a lateralized image of an object that could either agree with the label or not. Critically, the location of both cue and target was systematically manipulated. In 80% of the trials the cue was presented on the same side of the visual field as the target (valid trials) and in 20% the cue and target location mismatched (invalid trials). To test the generalizability of our paradigm, we also manipulated for the semantic category (i.e. animacy) of the objects, using animals (dolphins and sharks) and vehicles (motorbikes and scooters). As an initial validation of the category cueing paradigm, we found a cue validity effect despite the complex nature of both label and stimuli, as well as the expected basic level advantage (faster and more accurate categorization at the basic rather than at the subordinate level). Critically, we found that the strength of the cue validity effect varied as a function of both categorization level and semantic category: categorizing animals at the basic level resulted in larger cue validity effects than in the subordinate level. In contrast, categorizing vehicles at the subordinate level elicited larger cue validity effects than at the basic level. These findings demonstrate that spatial attention can be modulated by object knowledge and semantic categorization, suggesting a strong interaction between the two systems.

56.4072 **Which Cereal Bar? Choose or Reject, does it Matter?** Ester Reijnen[1](ester.reijnen@zhaw.ch), Swen Kühne[1], Jeremy Wolfe[2]; [1]Zurich University of Applied Sciences, [2]Brigham & Women's Hospital / Harvard Medical School

Food in several European countries is labeled with traffic light labels: Simple color-coding labels sugar, fat, saturated fat, and salt content (e.g., green = low). How do observers use this information to make decisions? Two cereal bars, labeled as containing equal calories, were presented. One had two red (bad) and two green (good) traffic lights. The other had four neutral, orange lights. 605 observers were asked to choose between the two or to reject one of the two: Obviously, the same 2AFC choice in both cases. If the red/green bar is chosen over the all-orange bar on X% of trials, it should be rejected on 100%-X% of trials. However, when the sugar was colored green, the red/green bar was chosen 64% of the time on choose trials but rejected in favor of the orange bar 55% of the time on reject trials (64% + 55%=119% > 100%, z = 3.14; p < .001). That is, the red/green bar was bought more often in the choose than in the reject condition (64% vs. 45%, z = 3.07; p < .01). If sugar was red, the situation is reversed: red/green bar chosen only 21% but 35% of the time on reject trials (21% + 35%=56% < 100%, z = 7.18; p < .001). That is, the red/green bar was selected less often in the choose than in the reject condition (21% vs. 65%, z = 7.35; p < .001). Since both bars have equal calories, they should be bought with equal probability. However, two factors interact to shape behavior. Observers are swayed by the good / bad label on sugar and they avoid vivid red/green information when asked to reject while favoring the vivid information when asked to choose. Knowledge of these rules can be used to shape consumer behavior.

56.4073 The Variable Role of Abstraction in the Neural Representation of Categories in the Visual System

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Categorization is crucial to how we make sense of the visual world. Using fMRI coupled with multivariate pattern analysis (MVPA) researchers have investigated the structure of categorical representations in the visual system. An open question is the role of abstraction in the structure of these representations. One possibility is complete abstraction across category members, or the representation of a prototype; another is the representation of each exemplar. Between these extremes is a continuum of intermediary models varying in level of abstraction (Vanpaemel and Storms, 2008). We investigated whether these intermediary models might reflect a variable role of abstraction in the neural representation of novel visual categories. Stimuli consisted of 16 annular square-wave gratings (1.5-8° eccentricity) varying in orientation (45, 75, 105, 135°) and spatial frequency (.25, .5, 1, 2 cyc/deg). Representational similarity analysis (RSA) was used to construct neural dissimilarity matrices (DM) for each participant (N = 10) from V1 functional data. After testing for across subject reliability of neural DMs, a group-averaged DM was found to be highly correlated with a model DM of the stimulus space (Spearman's $\rho = .92$, $p < .001$). Multidimensional scaling was then used to construct a 2D neural space. Separate groups of subjects performed distinct categorization tasks, and were trained to label (linearly and non-linearly separable) subsets of the stimuli, and generalize the learned categories to the remaining stimuli. The neural space served as input to different formal models of categorization in order to determine which best captured the choice behavior of observers in the categorization tasks. Across categorization tasks we found a variable role for abstraction, which speaks against a dichotomous approach to abstraction in the neural representation of visual categories.

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56.4074 The Easy-to-Hard Advantage with Real-World Visual Categories

Brett Roads[1,2](brett.roads@colorado.edu), Buyun Xu[3], June Robinson[4], James Tanaka[3]; [1]Department of Computer Science, University of Colorado Boulder, [2]Institute of Cognitive Science, University of Colorado Boulder, [3]Department of Psychology, University of Victoria, [4]Department of Dermatology, Feinberg School of Medicine, Northwestern University

Previous work on visual category learning has demonstrated that the easy-to-hard approach (i.e., train with easier items earlier and difficult items later) can benefit learning outcomes. However, it is unclear whether previous findings generalize to the complex category structure found in real-world categorization tasks. We investigate the easy-to-hard advantage by training participants to distinguish between benign and malignant skin lesions. To determine item difficulty, we employ a novel approach that leverages an exemplar-level psychological representation and model of human similarity judgments. The representation and similarity function allow us to compute an ease value for every exemplar. Ease is defined as the probability that a participant will classify a given exemplar correctly. Specifically, ease is proportional to the sum of the similarity between the given exemplar and all other exemplars in the same category. Ease takes into account multiple aspects of category structure, such as within- and between-category variability. The stimuli for each category are binned into easy, intermediate, and hard items based on the ease value. In the easy-to-hard (hard-to-easy) training policy, easy (hard) items are learned on day 1, easy and intermediate (hard and intermediate) items are learned on day 2, and all items are learned on day 3. On each day, training continues until 90% accuracy is achieved. Participants were given a pre-test before the first training day and a post-test one day after the third day of training. Pre- and post-test items consisted of images not seen during training. Both groups were able to learn the task as indicated by a significant d' improvement from 0.35 prior to training to 1.61 after training. Critically, participants in the easy-to-hard condition required almost 30% fewer training trials than participants in the hard-to-easy condition.

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56.4075 Memory for retinotopic locations is more accurate than memory for spatiotopic locations, even when intending to reach.

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To successfully interact with objects, we must maintain stable representations of their locations in the world. However, their images on our retina may be displaced several times per second by large, rapid eye movements. Are we able to form a seamless world-centered (spatiotopic) representation of objects' locations across eye movements? Golomb & Kanwisher (2012 PNAS) found that memory for an object's location is more accurate in gaze-centered (retinotopic) than world-centered (spatiotopic) coordinates, and that spatiotopic memory progressively deteriorates more than retinotopic memory with each eye movement. This suggests that the native coordinate system of visual memory is retinotopic, raising questions about how we effectively act on objects in the world. One possibility is that perception and action rely on different coordinates; that is, the intention to act on an object engages more ecologically-relevant spatiotopic representations. Here, we investigated whether the intention to act on an object's location could improve memory for its spatiotopic location. Twelve participants were asked to remember a spatial location across a short delay, during which they completed a variable number of eye movements (0-2). Participants completed four versions of this task: they reported either the retinotopic or spatiotopic location, either using a mouse to click on the remembered location (as in Golomb & Kanwisher, 2012) or using their finger to reach and interact directly with the touchscreen. We again found a pattern where spatiotopic errors were greater and accumulated faster than retinotopic errors in the mouse task. Critically, we found a similar pattern in the reaching task; if anything, spatiotopic errors were amplified. These results further support the hypothesis that spatial memory is natively retinotopic—even in in cases where spatiotopic coordinates are particularly behaviorally relevant, participants are still more accurate at remembering locations in retinotopic coordinates.

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56.4076 The effects of different types of human-object interactions on the ventral occipitotemporal cortex

Huichao Yang[1](yanghuichao89@gmail.com), Chenxi He[1], Xiaoying Wang[1], Zaizhu Han[1], Yanchao Bi[1]; [1]School of Brain and Cognitive Sciences, National Key Laboratory of Cognitive Neuroscience and Learning & IDG/McGovern Institute for Brain Research, Beijing Normal University

The human ventral occipitotemporal cortex (VOTC) contains clusters that are preferentially activated by different domains of objects. A currently prevailing hypothesis is that VOTC functionality is driven by its large-scale connections that support humans' different interactions with various domains of object: manipulation for small artifacts, navigation for scenes, and social interaction for conspecific entities. To test this hypothesis, we trained participants to learn associating meaningless graphs with these three types of human-object interactions by watching cartoons. BOLD fMRI responses were collected for the following sessions: viewing of the graph (one back task), cartoon watching for the three types of interactions with the graphs, viewing of the graph (one back task). The following results were obtained: 1) watching cartoons of human figures performing the three types of interactions with the same graphs elicited whole-brain activation patterns that generally corresponded to the domain-specific regions for artifacts, scenes, and faces/humans, respectively; 2) in VOTC, the lateral occipital temporal cortex (LOTC) was selectively activated when watching manipulation cartoons and the parahippocampal place area (PPA) when watching navigation cartoons; 3) the functional connectivity strength between LOTC and another manipulation-activated region (supramarginal gyrus) during the manipulation learning significantly predicted how strong the LOTC activity to graph viewing changed by training, and also how well the participant memorized the graph-manipulation association. No such effects were observed for PPA. In summary, establishing the mapping between a visual object and a type of manipulation, supported by the functional coupling between LOTC and supramarginal gyrus, induced the domain-specific activation changes for visual perception in LOTC. The social interaction and navigation interaction, however, did not have such an effect on the VOTC activation. These findings highlight the role of human interaction and functional coupling among relevant networks for the LOTC's domain-specific activation for small artifacts.

56.4077 **Categorization in monkey inferior temporal cortex determined by image features, not acquired knowledge** Xiaomin Yue[1](yuex@mail.nih.gov), Marissa Yetter[1], Leslie Ungerleider[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health, National Institutes of Health

Our visual system represents visual objects according to categories. One of most basic categories is the animate vs. inanimate division. Based on results from recent studies (Livingston et al., 2015; Perrinet & Bednar, 2015) and our earlier study (Yue et al., 2014), we hypothesized that animate vs. inanimate categorization is: 1) encoded by multivoxel activity patterns; and 2) influenced to a large degree by the unique image-based features that distinguish animate from inanimate stimuli. Using a slow event-related design, we acquired fMRI scans in three fixating rhesus macaques in response to a large set of visual stimuli, including 47 sub-categories with 20 images per sub-category. We employed curved and rectilinear Gabor filters to quantify curved and rectilinear image-based features. As hypothesized, we found that multivoxel activity patterns measured with support vector machine classification encoded animate vs. inanimate categories in the monkey inferior temporal cortex; multiple dimensional scaling failed to categorize individual exemplars in the animate vs. inanimate division. This result suggests that animate vs. inanimate categorization is represented in the brain in a high dimensional space, and is not a 2-dimensional representation. Moreover, curved and rectilinear features explained a significant amount of variance in the fMRI activity patterns that encoded animate vs. inanimate categories. Our results thus support our hypothesis that animate vs. inanimate categorization in the inferior temporal cortex is influenced to a large extent by the unique image-based features (such as curved and rectilinear features) that distinguish animate vs. inanimate stimuli. The results argue against the notion that categorization stems from acquired semantic knowledge of the characteristics that distinguish object categories, and instead suggest that the unique image-based features that distinguish animate vs. inanimate stimuli give rise to the formation of categorization in the macaque inferior temporal cortex.

OBJECT RECOGNITION: FEATURES

Tuesday, May 23, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4078 **Relational Representation of Body Parts Revealed by Adaptation** Alexander Bratch[1](abratch92@gmail.com), Stephen Engel[1], Daniel Kersten[1]; [1]Department of Psychology, University of Minnesota

Human observers are remarkably proficient at identifying and discriminating other humans in their perceptual environment. What representations underlie this success? We tested whether humans represent the relations between body parts using a behavioral adaptation paradigm. In Experiment 1, observers viewed digital renderings of arms, and were asked to judge the relative length of the forearm compared to the upper arm ("too long" vs "too short"). Forearms were presented at 0 (veridical), ±5, ±10, and ±15 percent scaled lengths. After completing baseline judgements, observers adapted to an arm containing a relatively shortened forearm (by 25%) for either 2 minutes or 10 minutes, after which they completed post-test judgements. Psychometric functions relating observer response to arm scaling were computed, and PSEs were estimated as the 50% point of the function. Following adaptation to a short forearm, observers in the 10 minute group perceived forearms as significantly longer (by 6%, $p < 0.05$), an effect which decayed over time. A smaller trend was observed in the 2 minute group (~3%, $p = 0.16$), consistent with past work showing adaptation, as opposed to short-term bias, becomes stronger as exposure duration increases. In Experiment 2, using similar procedures, observers were tested with arm images at the same orientation as the adaptor and with images rotated by 90 degrees. Post-test trials were preceded by 4 seconds of top-up adaptation. Following adaptation to the short forearm, observers perceived forearms as significantly longer at both the orientation of the adapter (10%, $p < .01$) and at the 90 degree rotation (3%, $p < .05$), though the effect was reduced in the 90 degree condition. Taken together, the results of Experiments 1 and 2 suggest that humans perceive bodies using representations of relative limb length, and that these representations are at least partially invariant with respect to image rotation.

56.4079 **Principal Axes of Real-World Objects: Evidence from Orientation Reflection Errors** Thitaporn Chaisilprungraung[1](tchaisi1@jhu.edu), Joseph German[2], Michael McCloskey[3]; [1]Johns Hopkins University, Department of Cognitive Science, [2]Johns Hopkins University, Department of Cognitive Science, [3]Johns Hopkins University, Department of Cognitive Science

According to several theoretical perspectives, the spatial structure of an object is represented with respect to the object's most important axis—the object principal axis (e.g., Marr & Nishihara, 1978). For objects with an elongated or a symmetrical shape (e.g., a pen, a wine glass), available evidence suggests that the principal axis may correspond to the shape's axis of elongation or symmetry (e.g., Quinlan & Humphreys, 1993; Sekuler & Swimmer, 2000). For objects with more complex shapes, less is understood about how the principal axis is defined. We examined a class of real-world objects consisting of an elongated base and a protruding part—that is, objects with shapes resembling the capital letter 'L' (e.g., a hatchet with a large protruding blade; see Fig.2 of the supplementary materials). We asked whether the principal axis was better aligned with the object's main elongation axis (e.g., the hatchet's handle), or with an axis that spanned the global contour of the object (here referred to as the object 'contour axis'). The paradigm we used involved analyzing the pattern of reflection errors participants made in an orientation recall task. Participants were asked to report the orientation of an object they previously saw. In trials where a reflection error was made, we identified the object's axis of reflection (Fig.1). This experimental paradigm was built on the previous finding (e.g., Gregory & McCloskey, 2010) that when participants made an orientation reflection error, they tended to reflect the object across its internal principal axis. Our results suggested that the principal axes of the 'L'-shaped objects were better aligned with the object's axis of elongation (Fig.4) than with their contour axes. Overall, this finding sheds light on how individual parts within an object may interact to shape the representation of the object's global spatial structure.

56.4080 **Nonconscious Enhancement of Peripheral Vision** Eric Clapham[1](eric.clapham@bhsu.edu), Alex Richardson[1], Kerry Tarrant[1], Jessica Decker[1]; [1]Black Hills State University

Considering the anatomy and organization of the visual system, perception in the periphery should be a highly blurry experience, but it isn't. Anecdotally, we seems to experience a detailed visual awareness throughout our visual fields. The obvious culprit for such enhancements is top down processing. We hypothesized that the information driving these top down affects is obtained during scene scanning. To address this line of thinking a nonconscious repetition priming paradigm was used to simulate the conditions occurring during scene scanning, namely a brief exposure to an image that is not necessarily rememberable. Our goal was to explore how such information might contribute to the experience of visual consciousness, one that seems filled with details and clarity. All experimental trials began with a fixation point, then the presentation of a 30 ms masked prime (full spectrum and high or low spatial frequency images), followed by two briefly presented target images (150 ms). Target stimuli were filtered to create equally appearing blurry images. Participants, however, believed that the target items varied in level of blurriness. Target stimuli were either congruent (i.e. a filtered version of the previously presented prime), or incongruent (i.e. a filtered images that differed from the prime). The experimental task was to indicate which of the 2 target images was more easily identified or clearer. Consistent with previous findings congruent target images were perceived as the clearer and more identifiable images significantly more often than was expected. The results suggest that limited awareness of objects within one's visual environment can enhance the perceived clarity of those items, even as they drift into peripheral visual fields. Taken together these results provide compelling evidence that a large portion of our visual experience is being shaped by information gathered during scene scanning, even in the absence of conscious awareness.

56.4081 An Investigation of the Effect of Prediction on Object Perception

Sarah Cook[1](sarahcook@email.arizona.edu), Diana Perez[1], Mary Peterson[1,2]; [1]Department of Psychology, University of Arizona, [2]Cognitive Science Program, University of Arizona

Can prediction affect the perceived sharpness of an object's edges? We tested whether a masked word prime affected the point at which two stimuli with borders varying in blur were perceived as equally blurry (the Point of Subjective Equality). Participants viewed 180-ms exposures of two small, enclosed black silhouette objects on a gray background. The Test object varied in blur, from low to high levels across trials, while the Standard object remained at a constant medium blur value. In Experiment 1, one object was familiar; the other (PR) was novel, created by rearranging the parts of the familiar object. Both objects were Test and Standard objects equally often. Before the object display, a prime word (related or unrelated to the Test) was presented outside of awareness. Participants reported which object appeared blurrier. We hypothesized that the familiar Test would appear sharper when preceded by a related vs an unrelated prime. Experiment 2 was identical to Experiment 1, with small changes in masking procedures. Neither experiment revealed an effect of prime. However, in both experiments, the familiar object was perceived as sharper than the PR object (Exp 1, p = < .001, n = 17; Exp 2, p = < .001, n = 13). These results may be due to the activation of object memories by the familiar Test, and subsequent modulation of the mismatch between predicted sharp edges and blurry Test edges. Alternatively, they could be due to response bias, with participants biased to choose the PR object as blurrier when there were small differences in blur. Experiment 3, currently underway, uses a same/different judgment to eliminate response bias. If we still find that familiar objects are perceived as sharper, these results will support the claim that percepts of familiar objects are not veridical representations of stimulus information, but are biased by object memories.

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56.4082 Two-tone object recognition poses a major challenge for the developing visual system until late in childhood.

Tessa Dekker[1](tes.m.dekker@gmail.com), Theo Cooper[1], Aisha McLean[1]; [1]University College London

While many basic visual abilities develop during the first years of life, several skills improve substantially until late childhood. Clear insight into what these abilities are and why they develop so late is currently lacking. Here we provide a striking demonstration of fundamentally different object processing skills in children and adults. We presented 53 children aged 4-12 years and control adults with 20 different two-tone images on a touchscreen. In these images, original highlights and shadows were shown as solid blacks and whites so that outlines were obscured and objects difficult to recognise. On each trial, we first tested if participants could identify the object in the two-tone image. We then presented participants with the original image, firstly to ensure they knew all objects, secondly because this induces mandatory two-tone object recognition in typical adults. We then presented the two-tone image again, measuring recognition by asking participants to point out two clearly identifiable object features. We computed the deviation from where these features were pointed out in the original, correcting for individual aiming precision. Strikingly, and in line with previous reports (Kovacs & Eisenberg, 1998; Yoon et al., 2003), 4-5 year-olds' aiming points deviated hugely from the correct feature, demonstrating no change in two-tone recognition after seeing the original. This is unlikely to be due to attention or memory lapse, as the original was shown simultaneously or just before the two-tone. Feature localization and initial two-tone object recognition improved gradually with age between 4-12 years, with adult-like performance only in 9 to 12-year-olds. Thus, until late childhood the ability to recognise objects given poor visual information continues to improve substantially. This may reflect changes in visuospatial processing (e.g., global vs. piecemeal processing), object knowledge, or both in tandem.

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56.4083 A Bistable Figure in a Thousand-Year-Old Bowl

Elizabeth Dobbins[1](egdobbin@samford.edu), Allan Dobbins[2]; [1]Dept. of Biology, Samford University, [2]Dept. of Biomedical Engineering, University of Alabama at Birmingham

The people of the Mimbres river valley in the southwestern United States are noted for their distinctive pottery, which flourished from roughly 1000-1150 CE. Painted pottery is found in sites in contiguous regions of southwestern New Mexico, southeastern Arizona and northern Mexico. Although different types of earthenware were fabricated, the most common decorative pieces were bowls, of which well over a thousand survive in museums and private collections. The outside of the bowls were usually unadorned, while the inside contained geometric patterns, animal or human figures, or both. In addition, a variety of chimeric animals and animal-humans are depicted. Curiously, while some insects, animals, and birds are found repeatedly, others, native to the area, and presumably a significant part of the life of these hunting people, such as elk, are rare or absent. Rabbits are one of the most commonly depicted animals and, while they occur in different configurations (isolated rabbit, two opposed rabbits, two rabbits in mirror image configuration), they are generally unambiguously rabbits or hares. In the Maxwell Museum of Anthropology at the University of New Mexico, we discovered one bowl in which two rabbits at opposite sides of the bowl have bodies that merge into one in the center. When one rotates the bowl by a quarter turn, it is likely that one sees two ducks instead of two rabbits. The Mimbres duck-rabbits differ from the modern version in having a body, and the alternative head-body interpretations are rotated, rather than directly opposed. With modern Western observers, we report that the probability of seeing each interpretation varies with the orientation in which a picture of the bowl is presented. While it is impossible to know the artist's intentions, it seems likely that the Mimbres potters and their audience would have been aware of both interpretations.

56.4084 Using eye-tracking to examine feature and component priming in adults and 3- to 5-year-old children.

Peter Gerhardstein[1](gerhard@binghamton.edu), Sarah Olsen[1], Alecia Moser[1]; [1]Dept of Psychology, Binghamton University-SUNY

The present study utilized a gaze-contingent adaptation of the visual world paradigm (VWP) to replicate and extend a well-known test (Biederman & Cooper, 1991) of Biederman's object recognition theory in adults and 3- to 5-year-old children. The VWP uses a priming procedure to assess the influence of a stimulus on moment-by-moment gaze of subjects following the prime. Subjects in this study were presented with a feature- or parts-deleted image, and were asked to identify that image from a four-item array containing the identical image (target), its complementary contour-deleted image (complement), a different exemplar of same object category (different exemplar), and an unrelated distractor (distractor). Gaze proportion to each of the four areas of interest (AOIs) was calculated in 24 msec bins from the onset of the array for a period of 1600 msec. Proportions were analyzed using a cluster-based divergence analysis. Adult results indicate a replication of the classic finding using eye-tracking and the VWP. Specifically, looks to the parts-based target exceeded looks to the complement early on (384 msec), indicating a lack of priming to the parts complement. Conversely, looks to the feature-based target and complement remained equivalent until much later in the trial (1032 msec), suggesting that the adults did not show a clear ability to discriminate between the two images, and indicating visual priming for the non-primed feature-based complement image. Children tested showed an overall difficulty with the feature-deleted images, in that looks to any of the four objects did not diverge until late in the trial (672 msec), at which point children appeared to show an adult-like pattern, indicating visual priming of the non-primed feature complement as well as the primed target. Children also showed an adult-like pattern when processing the parts-deleted images, but again were slower overall and showed less pronounced differences in gaze preference.

56.4085 The Relative Contribution of Features and Dimensions to Semantic Similarity

Marius Cătălin Iordan[1](mci@princeton.edu), Cameron Ellis[2], Daniel Osherson[2], Jonathan Cohen[1,2]; [1]Princeton Neuroscience Institute, Princeton University, [2]Psychology Department, Princeton University

Similarity governs our perception and reasoning, helping us to relate new stimuli to their long-established category labels and to generalize learned behaviors to novel situations. Similarity has often been explained as aris-

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ing from commonality of features and parts (Attneave, 1950; Tversky & Hemmenway, 1984) and as a defining metric for categorization processes (Ashby & William 1991; McClelland & Rogers 2004). However, it remains unclear how feature-based (implicit) and explicit components of similarity combine to give rise to perceptual similarity for real-world objects. Here, we collected pairs of explicit unconstrained ('How similar are these two animals?') and dimension-cued similarity judgments, as well as feature ratings used to derive an implicit measure of similarity, for ten basic-level animals across twelve similarity dimensions (six objective: e.g. size; six subjective: e.g. cuteness), presented as either text labels or short videos. Participants' reported explicit similarity judgments were virtually unaffected by presentation modality (r=0.95). Feature-based similarity significantly predicted dimension-cued similarity (top half dimensions: r=0.63--0.92,p< 0.001) and dimension-cued similarity significantly predicted unconstrained similarity (top half dimensions: r=0.78--0.96,p< 0.001). However, feature-based similarity could not explain unconstrained similarity on a dimension-by-dimension basis, but only by linearly combining all implicit similarity dimensions into an aggregate measure (equal-weight: r=0.35,p< 0.05; optimal-weight: r=0.65,p< 0.001). Furthermore, we observed an interaction between subjectivity and explicitness: subjective implicit dimensions explained more variance for explicit similarity, while objective explicit dimensions explained more variance for unconstrained similarity (subjectivity main effect p< 0.01, interaction p< 0.01). Together, our results suggest that feature-based and dimension-cued similarity may combine in a non-trivial way based on feature subjectivity to help generate similarity judgments. Given recent work showing interaction of cognitive control and infero-temporal regions in computing similarity judgments (Keung et al., 2016), our results provide an interesting hypothesis for elucidating the neural components of similarity and its susceptibility to attention and other sources of bias.

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56.4086 **Perceptual processing load in shape discrimination: stars are seen easier than ovals?** Iliya Ivanov[1](iliya.ivanov@uni-tuebingen.de), Sandra Wagner[1], Siegfried Wahl[1]; [1]ZEISS Vision Science Lab, Institute for Ophthalmic Research, Centre for Ophthalmology, University of Tuebingen, Tuebingen, Germany

Discrimination thresholds for radial deformations of closed circular contours, which may outline simple shapes such as stars, squares and ovals, fall within the hyper-acuity range. This extreme performance of the visual system may be accounted for by a global pooling processing after the local features are extracted in the earlier stages. We employed the pupillary response as a measure of the processing load in a shape discrimination task, where subjects had to detect deviations from circularity on different shapes (RF patterns). Thus we addressed the question of whether different RF patterns or their parts are processed differentially by the visual system. Pupil dilation was sampled at 1000 Hz while 4 subjects discriminated between modulated and non-modulated versions of RF patterns. Subjects sat in a dim room and their chin and forehead were stabilized. Stimuli with radial frequency of 2 (ovals, RF2), 5 (stars, RF5) and one cycle from RF5 (RF1) were presented at 100% contrast in a temporal 2AFC procedure and subjects had to respond in which of the two intervals the modulated stimulus was presented by a key press. Task-evoked pupillary responses (TERP) for high (100% detected stimuli) and low (chance level detection) amplitude modulations were analyzed. Preliminary results show that TERPs were higher (increased pupil dilation) for RF2 than for RF5 at both high and low modulation amplitudes. Further, the TERP was lower (decreased dilation) at low amplitude modulations. TERP functions for RF5 and RF1 exhibited distinct shapes. Pupil dilation decrease at low amplitudes indicates that processing load in the visual system is low when shape differences cannot be detected. Pupil dilation decrease with radial modulation increase and distinct TERP function shapes suggest that the stimuli investigated here are processed differentially by the visual system, possibly by a mechanism that pools global information at higher cortical levels.

56.4087 **We see the forests before the trees but how do they combine? Shape information combines linearly across multiple scales** Georgin Jacob[1,2](georginjacob@gmail.com), SP Arun[1,2]; [1]Center for Neuroscience, Indian Institute of Science, Bangalore, India , [2]Department of Electrical Communication, Indian Institute of Science, Bangalore, India

A classic finding in vision science is that we see the forest before we see the trees. For example, when seeing a circle made of diamonds, humans can report the global shape (circle) faster than they report local shape (diamonds). Although such hierarchical stimuli have been extensively studied, we know little about their underlying representation: how do large and small scale features combine in an object? Do they interact, and if so, how? More generally how does shape information combine across multiple scales? To address these fundamental questions we performed a number of experiments to understand the representation of hierarchical stimuli in perception. In each experiment we measured the perceived dissimilarity between pairs of stimuli using oddball visual search. In Experiment 1, we asked whether the net dissimilarity between shapes differing at both global and local levels could be understood using dissimilarities at the individual scales. Dissimilarity between hierarchical stimuli was explained almost entirely as a linear sum of contributions from shape relations at the global level, at the local levels and from cross-scale interactions across and within objects. Thus, features across multiple spatial scales combine linearly. The scale, position and configuration of local elements can contribute to the percept of the global shape. In Experiment 2, we compared the representation of hierarchical stimuli with shapes made of an external contour and an internal local shape. Both were highly correlated, but we observed weaker cross-scale interactions for exterior-interior shapes. In Experiment 3, these cross-scale interactions increased when the interior shape moved closer to the external contour or increased in size. Taken together, our results show that shape information across multiple scales in an object combine linearly, and delineate the factors that influence cross-scale interactions.

56.4088 **Object detection and localization for free from category-consistent CNN features.** Hieu Le[1](hle@cs.stonybrook.edu), Chen-Ping Yu[3], Dimitris Samaras[1], Gregory Zelinsky[1,2]; [1]Computer Science Department, Stony Brook University, [2]Psychology Department, Stony Brook University, [3]Psychology Department, Harvard University

In recent work we introduced the idea of Category-Consistent Features (CCFs): commonality-based generative features that occur both frequently and consistently across the exemplars of an object category (Yu, Maxfield, & Zelinsky, 2016, Psychological Science). Attention can be guided preattentively to even complex object categories, but computationally-explicit theories of categorical guidance are still in their infancy. Here we show that limited automatic object detection and localization can be obtained by identifying the CCFs of a category using a convolutional neural network (CNN; VGG-19, Simonyan & Zisserman, 2015, ICLR) and then integrating their collective activations over proto-objects. Given a set of exemplar images for an object category, and a global pool of visual features from a pre-trained CNN, the CCF filters (CNN-CCFs) for this category are selected as the filters that are strongly and consistently activated by this category's exemplars. The collective responses of the CNN-CCFs are then pooled into proto-objects (merged visual fragments following a superpixel segmentation), and these are integrated into larger objects by computing the geodesic distances between the segmented proto-objects based on their boundary strengths. The intensity-based geodesic distances between proto-object boundaries act as a spatially-focused attentional "hand" that binds the proto-objects into a stable object, similar to the account from Coherence Theory (Rensink, 2000, Visual Cognition). Using this two-step approach we achieved, in a fully unsupervised way, state-of-the art object class localization accuracies in VOC2007, VOC2012, and the Object Discovery datasets with CorLoc scores of 41.2%, 47.5%, and 85.7%, respectively. Using a held-out set of ImageNet categories for testing, we also showed that our method is able to localize unknown categories that were not used for pre-training the CNN, again achieving state-of-the art accuracy (70.7%). Our results suggest that the locations of objects, both learned and novel, can be computed (without supervision) from CCFs integrated across proto-objects.

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56.4089 **A novel game for discovering visual features for object recognition.** Drew Linsley[1](drew_linsley@brown.edu), Sven Eberhardt[1], Pankaj Gupta[1], Thomas Serre[1]; [1]Department of Cognitive, Linguistic and Psychological Sciences, Brown University

A central goal in vision science is to understand what features are used by our visual system to process visual scenes. Reverse correlation methods are often used for uncovering the internal representations supporting

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recognition. This involves analyzing the statistical relationship between participants' decisions and visual perturbations applied to different visual locations across many trials. While these and other methods have successfully identified visual features diagnostic for the recognition of faces and other synthetic object stimuli, they require thousands of trials per subject and typically fail when applied to object classes with greater variability in their appearance. To rectify this, we introduce Clicktionary, a web-based game for assessing the importance of visual features for object recognition. Pairs of participants play together to identify objects: One player reveals image regions diagnostic of the object's category while the other tries to recognize the object as quickly as possible. Aggregating game-play data across players yields importance maps for individual object images, in which each pixel is scored by its contribution to enabling correct object recognition. These importance maps reveal object features that are distinct from those emphasized by saliency algorithms or those used by current state-of-the-art deep convolutional networks (DCNs) that are starting to approach human-level accuracy on certain visual recognition tasks. At the same time, we have found that the accuracy of DCNs can be further improved by "cueing" these networks to attend to visually relevant image areas during learning. Clicktionary is a novel method which, for the first time, enables the visualization of feature importance in object classes with high intra-class variability, opening up new research avenues to study the bases of mid- and high-level vision.

Acknowledgement: NSF early career award (IIS-1252951), DARPA young faculty award (N66001-14-1-4037)

56.4090 **Attractiveness of female and male body: comparison of subjective and objective measures** Slobodan Markovic[1](smarkovi@f.bg.ac.rs), Tara Bulut[1]; [1]Laboratory for Experimental Psychology, University of Belgrade, Serbia

The present study evaluated two hypotheses of human body attractiveness. The first is the Preference-for-average hypothesis: average female or male body shapes are most attractive, because they are "winning" evolutionary solutions for a certain population. The second is the Preference-for-supernormal hypothesis: according to the so-called "peak shift effect", the most attractive body is more masculine or feminine than the average, because it additionally stresses the crucial physical differences between genders. Forty-seven participants of both genders participated in the study. In the first part of the study we collected subjective measures: using a program for computer animation (DAZ 3D), participants created (1) most attractive and (2) subjectively estimated average female and male figures. These tasks were performed by adjusting the size of three body parts of both female and male figures: waist, hips and shoulders. Analyses showed no main effects of participants' gender for all subjective measures. The effect of task was significant for waist and shoulders: compared to average, most attractive female and male figures have broader shoulders and narrower waist. In the second part of the study we collected objective measures, i.e. participants' self-measures of waist, hips and shoulders circumference. Comparison of subjective and objective measures of waist-to-hip ratio (WHR) and shoulder-to-hip ratio (SHR) supported the Preference-for-supernormal hypothesis. Both female and male participants created figures which are generally more feminine (lower WHR) or masculine (higher SHR) than those created as average, and, interestingly, objective measures are less feminine or masculine than the ones subjectively estimated as average bodily proportions.

Acknowledgement: This work was supported by the Ministry of Education and Science of the Republic of Serbia, grant number 179033.

56.4091 **Amputees misperceive the size of artificial limbs** Ritika Mazumder[1](mazrm-17@rhodes.edu), Jason Haberman[1]; [1]Department of Psychology, Rhodes College

In creating prosthetic devices for lower-limb amputees, prosthetists make the limbs smaller than the corresponding intact limbs (along the width dimension) by about three percent (Mazumder & Haberman, VSS, 2015). This is in response to patients' report that the limb appears too 'bulky' if exactly matched in size to the intact limb. In a prior experiment, we explored whether such a perceptual bias manifested in non-amputee observers. Surprisingly, the results suggested that observers perceived the size of a prosthetic device as too small, and this was most evident in the context of whole, upright bodies. The direction of this bias was unexpected given clinical practice. The critical question, explored in the current set of experiments, is whether amputees, who may have experience and/or cortical reorganization due to their amputation, exhibit any perceptual bias when viewing prosthetic devices. Participants, all lower-limb amputees, viewed images of other amputees and, using the mouse, adjusted the width of the prostheses until it looked 'right.' Unexpectedly, amputees showed the same bias as non-amputees, adjusting the prosthetic limbs to be larger than the intact limbs by almost seven percent (i.e., it only looked 'right' when its width was greater than that of the intact limb). Although the bias persisted when the images were inverted, it was significantly reduced, suggesting configural processing enhanced the size misperception. While this bias contrasts with clinical practice, we hesitate to suggest the practice is misguided, as amputees' report of the limb being 'too big or bulky' might be driven by somatosensory representations rather than visual ones.

56.4092 **Background check: Perceptual grouping cues reduce novice holistic processing of birds** Cassady Olson[1](csolson@colgate.edu), Grace Luu[2], Zachary Cole[3], Jieyi (Crystal) Ding[3], Jessie Peissig[2], Cindy Bukach[3]; [1]Colgate University , [2]University of California, Fullerton, [3]University of Richmond

Perceptual grouping has been implicated as a mechanism for the holistic perception of faces. Using the composite task, Curby et al. (2013) found that holistic processing of faces, but not objects, is reduced when the backgrounds are misaligned and different colors. One implication of this study is that background color differences are enough to disrupt holistic processing of faces, but background color consistency is not enough to induce holistic processing for objects. Nonetheless, observers do sometimes show holistic processing of novice object categories (e.g., Greebles interleaved with faces). Recently, Bukach et al. (2015) found that novices processed birds holistically, but this novice holistic processing was negatively correlated with species matching ability. Here, we investigated whether novice holistic processing is influenced by perceptual grouping cues. Fifteen novices completed a bird composite task in which bird heads and bodies were always aligned, but background colors were either grouped (uniform color/aligned) or ungrouped (different colors/misaligned). Participants decided whether the cued part of sequentially presented bird composites were same or different, while attempting to ignore both the non-cued part and background changes. There was a significant interaction between congruency and grouping ($p = .045$). Surprisingly, the congruency effect was larger for ungrouped than grouped trials ($\Delta d' = .805$ vs. $.456$ respectively), opposite of the holistic processing pattern. This effect was driven solely by reduced accuracy for nonmatching congruent trials with a uniform aligned background. We speculate that whereas processing during incongruent trials was focused primarily on resolving the ambiguity of the target response, processing during congruent trials allowed more processing of background cues. The slower response times of non-matching trials suggest they may have been particularly vulnerable due to the need for more evidence or lack of confidence in the response. Perceptual grouping cues may compete with target responses in the composite paradigm.

56.4093 **The second elbow in number perception** Makayla Portley[1](mportle1@swarthmore.edu), Frank Durgin[1]; [1]Department of Psychology, Swarthmore College

Lurking in the number estimation data of Volkman et al. (1949) are two elbows, only one of which has been a focus of previous research. Volkman et al. distinguished the subitizing range from the estimation range based in part on a sharp inflection in the response-time function between numbers less than and numbers greater than about 5. Here we show that a second elbow, hitherto unnoticed in Volkman's estimation data occurs at about 20 in number estimation. Magnitude estimation data were collected for numerosity from participants tested individually in the laboratory (N=78). Undergraduates estimated the numbers of large luminance-balanced annular spots in one of four quasi-logarithmic ranges (Expt. 1: 1-224 or 26-224; Expt. 2: 1-72 or 9-224). Displays were circular with enclosing diameters varying in size by a factor of 1.5 (17° to 25°). Random spot arrays were flashed for 400 ms, after which the participant typed in a numeric estimate. Each participant saw each number in the range 6 times, for a total of either 192 trials (Expt. 1) or 144 trials (Expt. 2). When only numbers above 25 were presented, we replicated Krueger's (1972) observation that number estimates follow a power function with an exponent of about 0.7, but when ranges crossing 20 were presented, estimates changed over from being accurate (with exponents equal to or greater than 1) for numbers up to about 16 to underestimation with an exponent between 0.5 and 0.6 for numbers above 20. Both the sharp elbow in the estimation functions and

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the compressed scaling for higher numerosities were replicated in all three conditions where the ranges spanned across a numerosity of 20. Modeling based on occupancy (Allik & Tuulmets, 1991) did not account for the elbows. This second number elbow suggests that number estimation may be divisible into three regimes rather than two.

Acknowledgement: NEI R15 EY021026

56.4094 **Segmentation of the Human Body: How Does the Visual System Define Body Parts?** Catherine Reed[1](clreed@cmc.edu), Alison Harris[1], Madison Lodge[1], Grant Gaither[1]; [1]Psychology, Claremont McKenna College

How does the visual system define and segment the parts of the body? Although previous work suggests people categorize human body parts based on functional units that can be coordinated to perform actions, less research has focused on how body parts are defined within the long-term visuospatial body representation. Recent data on holistic body processing has shown that the visual system discriminates postures of upper body parts better than lower body parts, and local body-part configurations are processed together. However, neither study explicitly tested which body-part divisions were most salient. Here we examined how the visual system naturally segments the body schema into parts in two experiments. In Experiment 1 (n=23), participants were shown a human body in a neutral posture and determined whether two dots were on the same or different body parts. Body stimuli included front and back views of the body at 0° and 90° orientations. Equidistant dots were placed within a body segment (e.g., within the forearm), across a joint but within a body part (e.g., forearm and upper arm), and across body parts (e.g., torso and upper arm). Regardless of orientation and view, participants judged body segments separated by joints as different body parts. In Experiment 2 (n=30), we investigated whether body-part distinctions influenced distance judgments within the context of the body. In a successive matching task, participants determined whether two dots placed on neutral body postures were the separated by the same distance. Discrimination was generally better and faster for upper over lower body regions. Additionally, participants showed increased speed and accuracy for dots crossing parts compared to dots within a part, suggesting that the salience of part divisions influenced perception of the dots' locations. These results confirm that the spatial body representation is 3D, not-orientation specific, and salient part divisions define its topography.

56.4095 **RF shape channels: The processing of compound Radial Frequency patterns.** Gunnar Schmidtmann[1](gunnar.schmidtmann@mcgill.ca), Alexandre Desjardins[1], Frederick Kingdom[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University, Montreal, Quebec, Canada

Radial Frequency (RF) patterns are quasi-circular contours that are frequently used to investigate intermediate stages of shape processing. Combinations of RF patterns have been used to construct more complex shapes such as head contours. Previous studies have suggested that complex shapes may be encoded by multiple, narrowly-tuned RF shape channels. The aim of this study was to test the hypothesis that complex shape processing may be based on multiple, independent RF channels and to demonstrate the limitations such shape descriptors. Thresholds were determined for detection (circle vs. RF compound) and discrimination (RF compound vs. RF compound) of various weighted combinations (symmetrical and asymmetrical) of two RF components (RF3&RF5; RF3&RF8; RF4&RF7). If both RF components were processed by a common broadband channel, one would expect a substantial increase in sensitivity as the information from both components would be summed within the same channel (additive summation: AS). If the two components were processed independently by separate channels, one would expect only a slight increase in sensitivity for the compound compared to the components (probability summation: PS). The data were analyzed by a model for probability (PS) and additive summation (AS) under Signal Detection Theory (Kingdom, Baldwin & Schmidtmann, Journal of Vision, 15(5):1). Results show that summation of information from different RF components is consistent with AS. This suggest that the shapes tested here are processed by a broadly tuned mechanism. In addition, we demonstrate the mathematical limitations of RF patterns which make them an unlikely candidate for universal shape descriptors.

56.4096 **When and why does adaptation increase perceived number?** Emilie Shepherd[1](eshephe1@swarthmore.edu), Frank Durgin[1]; [1]Department of Psychology, Swarthmore College

Burr and Ross (2008) reported that adapting to low numbers of elements (like 12 dots) increased the perceived number of field of more dots presented to the same location. On average their data from 2 observers showed that about 42% more dots were required in an unadapted region to seem equivalent. We sought to replicate and extend their observation. In a first study, we tested effects of adaptation to patterns of 12 dots using the 7-second re-adaptation to a stationary pattern employed by Burr and Ross between test trials. The average effect size was about 30% (95% CI: 12%, 41%) for seven naïve subjects tested with gaze monitoring via eye-tracker. In a second study we sought to measure possible effects of attention by presenting the comparison field sequentially rather than simultaneously for half of our 17 new observers. We additionally tried to strengthen adaptation by showing 7 different adapting fields of 12 dots each (600 ms on; 400 ms off) rather than just one for 7 seconds. The effect size for sequential comparisons did not differ from that for simultaneous comparison, but the overall magnitude of adaptation was sharply reduced to about 15% for both (95% CI: 6%, 25%). At least three possibilities exist for the reduction in magnitude of the effect. First, the total adaptation time was only 60% of 7 s, and thus, the amount of adaptation might be simply time dependent. Second, the seven different adapting dot patterns might be virtually merged so that the adaptation region was more uniformly adapted compared to a single sparse adaptation stimulus viewed for 7 seconds. Finally, it remains possible that increased number perception is produced by superimposed afterimages of displays with low spatial frequencies – a process partly ameliorated by the variable flashing adaption displays.

Acknowledgement: NEI R15 EY021026

56.4097 **A concurrent investigation of perceptual separability and process arrangement using perceptually separable stimuli** Ru Zhang[1](ruzh0110@colorado.edu), Yanjun Liu[2], James T. Townsend[2], Micheal J. Wenger[3], Lisa A. De Stefano[3]; [1]Department of Psychology and Neuroscience, University of Colorado, Boulder, [2]Department of Psychological and Brain Sciences, Indiana University, Bloomington, [3]Department of Psychology, University of Oklahoma

General recognition theory (GRT, Ashby & Townsend, 1986) can be used to formally represent the hypothesis of perceptual separability, which can be tested using response frequency data collected in a complete identification (CID) task. Systems factorial technology (SFT, Townsend & Nozawa, 1995) can address four fundamental characteristics of information processing (architecture, stopping rule, capacity, and independence in rate) using the distributional behavior of RT in a double-factorial paradigm (DFP). GRT and SFT characterize different aspects of human information processing that, to date, have been considered separately. We report on the results of one part of an empirical effort to unite these two theoretical lines using the "speedometer" stimuli, that previously have been shown (Kadlec & Hicks, 1998) to be perceptually separable. Stimuli were presented in both CID and DFP tasks, first using a payoff matrix that encouraged unbiased responding and second using a payoff matrix biased in favor of specific responses. A total of 4 observers were tested. We found that, as expected, the bias manipulation systematically moved the decision criterion either away from or toward the favored category. Perceptual separability was more likely to hold in the unbiased condition than the biased condition, regardless of the valence of the bias, as evidenced by the tests of marginal response invariance and report independence under the framework of GRT. The survival interaction contrast from SFT indicated parallel exhaustive and coactive manners were implemented in both unbiased condition and biased condition. The conclusion drawn from GRT and SFT further confirms the inference that the investigated stimulus is perceptually separable. The results indicate that combining the measures of GRT with those of SFT provides greater strength in making inferences regarding the nature of individual information and processing.

Face Perception: Neural mechanisms and models

Wednesday, May 24, 8:15 - 10:00 am
Talk Session, Talk Room 1
Moderator: Roberto Caldara

61.11, *8:15 am* Idiosyncratic Neural Signatures of Face Discrimination - A Fast Periodic Oddball Stimulation Study

Lisa Stacchi[1](lisa.stacchi@unifr.ch), Meike Ramon[1], Joan Liu-Shuang[2], Roberto Caldara[1]; [1]Department of Psychology, University of Fribourg, Switzerland, [2]IPSY & IoNS, University of Louvain, Belgium

Western observers typically deploy a triangular fixation pattern encompassing the eyes and mouth during face recognition. Nevertheless, this average gaze pattern does not reflect observers' idiosyncratic strategies, which highlight individual-specific preferences. Whether similar preferences exist at the neural level remains an open question. To this aim, we recorded observers' electrophysiological responses during fast-periodic oddball stimulation (Liu-Shuang et al., 2013). While observers fixated the center of the screen, faces were presented at a high frequency rate with changes in identity every seventh image. Relative to the observers' fixation location, the position of the faces differed in 10 sampling positions, uniformly covering all the internal facial features through different sequences of trials. At the group level, we observed that faces presented in the conventional central fixation position elicited stronger right-lateralized periodic electrophysiological responses for the oddball face, hereby replicating previous findings. Interestingly, we also observed viewing position dependency for the fundamental frequency of the base response (i.e. 6Hz). Its higher harmonics on the other hand elicited a centrally distributed response, while the oddball frequencies led to topographically more heterogeneous responses. At the individual level, we observed clear idiosyncratic differences as a function of visual sampling position – both in terms of amplitude, as well as topography. While some observers showed more right-lateralized responses, others were relatively more left-lateralized. These findings stress the need of carefully considering inter-individual variability, as well as controlling for stimulus parameters, such as its location within observers' visual field. The observed differences in lateralization also challenge the notion of a universal right-hemispheric dominance involved in face discrimination. Finally, the different topographies associated with base and oddball frequencies highlight the potential need to reconsider the nature of neural processes generated by the fast periodic oddball stimulation.

61.12, *8:30 am* A highly effective approach in fMRI brain mapping of visual categorization

Xiaoqing Gao[1](dr.x.gao@gmail.com), Francesco Gentile[1,2], Bruno Rossion[1,3]; [1]Psychological Sciences Research Institute, Institute of Neuroscience, University of Louvain, Belgium, [2]Department of Cognitive Neuroscience, Faculty of Psychology and Neuroscience, Maastricht University, The Netherlands, Maastricht Brain Imaging Center (M-BIC), Maastricht University, The Netherlands, [3]Neurology Unit, Centre Hospitalier Regional Universitaire (CHRU) de Nancy, F-54000 Nancy, France

Despite measuring neural activity indirectly, functional magnetic resonance imaging (fMRI) has become the most important tool in mapping the human visual system. However, current fMRI measurements may suffer from low signal-to-noise ratio (SNR) in detecting high-level neural responses in individual brains, leading to low test-retest reliability in spatial activation maps. Here we developed a novel fMRI approach to map visual categorization with fMRI. As in EEG frequency-tagging (Rossion et al., 2015), we presented a large variety of natural images at a fast rate (6Hz) throughout the entire experiment to stimulate the visual areas continuously. By introducing transient switches to a target category (faces) at a slow fixed frequency (1/54 stimuli, i.e., 0.111 Hz), we obtained a periodic differential neural response that directly reflects category selectivity. A model-free Fast Fourier Transform (FFT) of hemodynamic activity in this paradigm achieved a two-fold increase in sensitivity (peak SNR) in comparison to a conventional block design, allowing us to map comprehensive extended face-selective areas including the anterior temporal lobe (ATL) in individual brains. Using diverse natural images, we created contrasts at both lower-level visual properties and higher-level category properties in successive images. While the lower-level contrasts were at random time points, the category contrast would only happen at a fixed frequency by design. Therefore, we effectively eliminated the influence of low-level visual cues and increased the specificity of category-selective response. As a result of high sensitivity and specificity, we achieved high test-retest reliability, which reached the highest values (80-90%) ever reported in this area of research. The power of a model-free fast periodic visual stimulation (FPVS) approach with a slow temporal resolution method opens a real avenue for understanding brain mapping of visual categorization.

Acknowledgement: ERC facessvep 284025 to BR and Marie-Curie/UCL postdoc fellowship to XG

61.13, *8:45 am* Being BOLD: The neural dynamics of face perception

Francesco Gentile[1,2](f.gentile@nin.knaw.nl), Justin Ales[3], Bruno Rossion[2,4]; [1]Netherlands Institute for Neuroscience (NIN), Amsterdam, The Netherlands , [2]Department of Cognitive Neuroscience, Faculty of Psychology and Neuroscience, Maastricht University, The Netherlands, [3]School of Psychology and Neuroscience, University of St Andrews, United Kingdom, [4]Psychological Sciences Research Institute and Institute of Neuroscience (IPSY), University of Louvain, Belgium

According to a non-hierarchical view of human cortical face processing, selective responses to faces may emerge in a higher-order area of the hierarchy, in the fusiform face area (FFA) independently from face-selective responses in the occipital face area (OFA), a lower order area. Here we provide a stringent test of this hypothesis by using fMRI with a very short sampling rate (TR=500 ms) and by gradually revealing segmented face stimuli throughout strict linear descrambling of phase information. We presented 15 seconds stimulation sequence of upright, inverted and scrambled faces changing in local contrast occurring every TR while preserving low-level visual information constant throughout the sequence (Supplemental Material). A single subject statistical analysis revealed that the appearance of a face shape in the sequence triggered highly significant fMRI activation in the predefined face-selective regions FFA and OFA of all six individual brains tested, both for upright and inverted faces. Three main effects were observed (Supplemental Material). First, the BOLD signal rose above baseline in the OFA before any differentiation between upright and scrambled faces, but not in the FFA for the majority of subjects. Second and in contrast with this result, the difference between upright and scrambled faces emerged later in the OFA than the FFA, showing face detection based on structural information first in the higher-order region of the cortical face network. Third and in line with behavioral responses, the face versus scrambled face difference appeared earlier in the sequence for upright than inverted stimuli, both in the FFA and OFA, thus revealing a face inversion effect in the time-domain for the first time in fMRI. Overall, these results support the non-hierarchical view of human cortical face processing and open new perspectives for time-resolved analysis at the single subject level of fMRI data obtained during continuously evolving visual stimulation.

61.14, *9:00 am* The dynamics of facial identity processing: an EEG-based image reconstruction study

Dan Nemrodov[1](dannem@gmail.com), Matthias Niemeier[1], Ashutosh Patel[1], Adrian Nestor[1]; [1]Department of Psychology at Scarborough, University of Toronto

Elucidating the dynamics of visual processing delineates a major area of inquiry in the study of face recognition. Yet, the fine-grained pictorial content of face representations and its temporal profile still remain to be clarified. To this end, here we use image reconstruction as applied to electroencephalography (EEG) data. Specifically, we record EEG data associated with viewing face stimuli in healthy participants; then, we exploit spatiotemporal information available in EEG patterns to reconstruct the visual appearance of corresponding stimuli. Importantly, the structure of visual representations is derived directly from one set of EEG data (e.g., elicited by viewing happy faces); then, the corresponding features are used for reconstruction purposes from a different EEG dataset (e.g., elicited by

neutral faces). Analyses based on sequential 10ms windows indicate that multiple intervals support successful feature derivation and image reconstruction. In particular, we note that reconstruction accuracy peaks in the proximity of the N170 component, as evinced by univariate analyses of the same data. Further, reconstruction based on aggregate data from a larger temporal window (50-650ms) shows a clear boost in accuracy over their smaller-window counterparts, consistent with the hypothesis that distinct visual information becomes available over time. Thus, theoretically, the current work sheds light on the time course of facial information processing; methodologically, it provides a first demonstration regarding the ability of image reconstruction to accommodate EEG data; and, last, from a translational standpoint, this work points to the possibility of affordable means for neural-based communication of visual information via EEG systems.

61.15, *9:15 am* **Spatiotemporal dynamics of face processing network studied with combined multivariate EEG and fMRI analysi**

Viljami Salmela[1,2](viljami.salmela@helsinki.fi), Ilkka Muukkonen[1], Jussi Numminen[3], Kaisu Ölander[1,2]; [1]Department of Psychology and Logopedics, University of Helsinki, Finland, [2]Aalto NeuroImaging, Aalto University, Finland, [3]Helsinki Medical Imaging Center, Töölö Hospital, University of Helsinki, Finland

Previous EEG and fMRI studies have shown that processing of facial information contains several temporal phases and that several brain regions are involved in analysis of facial expressions and identities. We used multivariate representational similarity analysis (RSA) to combine data from separately measured EEG and fMRI experiments in order to investigate spatiotemporal dynamics of face processing. The face stimuli involved neutral, happy, angry and fearful expressions, as well as morphed (50%) versions of the expressions. The stimuli contained four different identities, two male and two female, as well as all the identities morphed (33% and 67%) to each other. In total, we had 112 images (7 expressions x 16 identities). Event related potentials (ERPs) were calculated from the EEG. The differences between the ERPs elicited by facial manipulations were quantified with representational dissimilarity matrices (RDMs). The ERP RDMs were calculated from consecutive 10 ms time windows from -100 to 1000 ms after stimulus onset. With a searchlight RSA, fMRI RDM within each searchlight was correlated with all ERP RDMs. This resulted in a series of correlation maps showing spatiotemporal dynamics of face processing. Distinct temporal profiles (correlations between fMRI and ERP RMDs) were found in occipital, parietal, temporal and frontal face regions. At 110 ms, correlations peaked in lateral occipital complex (LOC) and occipital face area (OFA). At 180 ms, correlations peaked in early visual areas (V1-V3), OFA and in fusiform face area (FFA). In FFA another peak was found at 230 ms. Temporal areas showed two peaks at 250 ms and 400 ms. Finally, in parietal and frontal regions correlation peaks were found between 400 and 600 ms. The results show that RSA can be applied to combine ERP and fMRI data, and reveal precise spatiotemporal dynamics within the face processing network.

Acknowledgement: Academy of Finland

61.16, *9:30 am* **Dynamic Integration of Visual and Categorization Relevant Information in the Ventral Stream**

Nicola van Rijsbergen[1](nicola@psy.gla.ac.uk), Robin Ince[1], Guillaume Rousselet[1], Joachim Gross[1], Philippe Schyns[1]; [1]Center for Neuroimaging,Institute of Neuroscience and Psychology, University of Glasgow

In visual categorization tasks, an observer's behavior depends both on the task and on the information encoded from their visual field. Where, when and how does the brain's dynamic encoding of visual information combine with task demands to become a representation of task-relevant information that supports behavior? Eight observers categorized the expression (7-AFC, 'happy,' 'surprise,' 'fear,' 'disgust,' 'anger,' 'sad' plus 'neutral') of stimuli while we measured their single-trial MEG responses. On each of the 21,000 experimental trials/observer, with Bubbles (Gosselin & Schyns, 2001) we randomly sampled pixels from the original faces using Gaussian apertures distributed across 5 one-octave spatial frequency bands (S1-B). Using mutual information (Ince et al., 2015, 2016) we quantified in each observer the dynamic coding of specific stimulus features through the whole brain—i.e. 12,773 voxels, 0-400 ms post stimulus, 4 ms resolution. To relate feature coding in the brain to the observer's categorization behavior (i.e. correct vs. incorrect), we introduce information theoretic redundancy, the 3-way interaction between MEG source time course, stimulus feature, and observer response (Ince et al., 2016). Technically, redundancy quantifies how much of the trial-by-trial stimulus variation commonly affects both the MEG signal and the observer's behavioral response (S1-A). A compelling outcome is a space x time processing pathway in the brain of the specific features that supports categorization behavior. Across observers, we show that redundancy increases in early visual cortex from the onset of visual coding, suggesting that task demands inform the uptake of task-relevant features early on. Also, redundancy shows a sharp increase at 148 ms post stimulus, midway down the left and right fusiform gyrus (S1-C), relative to the linear increase in visual face coding. This suggests a time window and a locus for the shift from generic face feature coding to specific task-relevant feature coding in the brain.

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61.17, *9:45 am* **Interactions between dorsal location- and ventral face-processing regions during configural face processing: a combined TBS-fMRI study.**

Valentinos Zachariou[1](zachariouv@mail.nih.gov), Christine Gou[1], Nicole Mlynaryk[1], Leslie Ungerleider[1]; [1]Laboratory of Brain and Cognition, NIMH/NIH

Configural face processing, the processing of the spatial relationships among the features of a face, is considered vital for face perception. If configural face processing depends on spatial information, might this process involve interactions between the face-processing regions of the ventral stream and visuospatial processing regions of the dorsal stream? Here, we used thetaburst TMS (TBS) with fMRI to examine how interference of localized spatial-processing regions of the dorsal stream affects the BOLD activity and pattern of functional connectivity of face-processing regions in the ventral stream during a same-different face detection task. Participants were presented with two face exemplars, appearing simultaneously on a screen that could differ in terms of the shape (featural differences) or the spatial configuration of their features (configural differences; Zachariou et al. 2016). Featural and configural differences were matched in difficulty as measured by RT and accuracy separately for each participant. Dorsal spatial-processing regions acted as the active TBS sites and the vertex acted as the control site. When TBS was applied on the location-processing regions of the dorsal stream, the magnitude of the BOLD activity within the right occipital face area (OFA) and right anterior inferior temporal (aIT) regions decreased in response to configural but not featural face processing. The above effect was not observed for the vertex control site. Crucially, TBS on the dorsal location-processing regions decreased the level of functional connectivity between bilateral OFA, aIT, right fusiform face area (FFA), and the dorsal location-processing regions (the TBS targets), significantly more for configural than featural face processing. No changes in the pattern of functional connectivity were observed when TBS was delivered on the vertex control site for either face task. We conclude that the location-processing substrates of the dorsal stream exchange visusospatial information with face-processing regions of the ventral stream during configural face processing.

Acknowledgement: This project is funded by the NIH IRP

Perception and Action: The basis of decisions and actions

Wednesday, May 24, 8:15 - 10:00 am

Talk Session, Talk Room 2

Moderator: Jeroen Goossens

61.21, *8:15 am* **Subliminal Rotations During Eye Blinks for Redirected Walking**

Gerd Bruder[1](bruder@ucf.edu), Eike Langbehn[2]; [1]University of Central Florida, [2]University of Hamburg

Real walking while wearing a tracked head-mounted display (HMD) is considered one of the most natural forms of locomotion in a virtual environment (VE). However, a straightforward implementation of real walking in virtual reality (VR) installations is not possible considering that the available tracked space is limited. Redirected Walking (RDW) presents a perceptually-inspired solution to this challenge by introducing subliminal visual rotations of the VE around the observer's position. Previous work investigated the potential of saccadic suppression for masking of large discrete changes in the visual stimulus but suffered from false positives in the classification of saccades, resulting in detectable visual manipulations. In this work, we designed an eye tracked HMD setup which detects eye blinks instead of saccades and leverages change blindness for visual manipulations. We performed a user evaluation using the eye tracked HMD setup in a within-subjects design in which we analyzed the participants' sensitivity to trans-blink scene changes and identified thresholds of visually undetectable rotations in a virtual world. Our results show that change detectability depends on rotation angles and scene layout. Overall, eye blinks were found to be an applicable tool for guiding users on physical paths that deviate from the visually perceived paths.

Acknowledgement: Office of Naval Research (ONR)

61.22, *8:30 am* **Modeling Sensorimotor Behavior through Modular Inverse Reinforcement Learning with Discount Factors** Ruohan Zhang[1](zharu@utexas.edu), Shun Zhang[2], Matthew Tong[3], Mary Hayhoe[3], Dana Ballard[1]; [1]Department of Computer Science, The University of Texas at Austin, [2]Computer Science and Engineering, University of Michigan, Ann Arbor, [3]Center for Perceptual Systems, The University of Texas at Austin

In the context of natural behaviors, humans must gather information to choose between different task needs, such as avoiding obstacles or heading towards a target. The brain's neural reward machinery has been implicated in these action choices, and a technique called Inverse Reinforcement Learning (IRL) can be used to estimate reward functions from behavioral data. A frequently overlooked variable in IRL is the discount factor: how much a future reward matters compared to the current reward. If future rewards are too heavily discounted, a person could overlook a future obstacle, even though it incurs a large negative reward. We argue that reward, together with discount factor, defines a value surface for a single task. The reward controls the maximum height of the surface, and the discount factor controls how fast the reward decreases over time or distance, i.e., surface shape. Value surfaces are computationally easy to compose, hence multitask behaviors can be modeled by combining these surfaces. This leads naturally to a divide-and-conquer approach of IRL, called modular IRL, which estimates relative rewards for subtasks. We expand upon previous modular IRL models (Rothkopf and Ballard, 2013) to include estimating the discount factor, and justify its correctness theoretically and experimentally through computer simulations as well as human experiments. We collect human navigation data in a virtual reality environment. Subjects are instructed to do a combination of following a path, collecting targets, and avoiding obstacles. We show the rewards and discount factors estimated from our algorithm reflect task instructions, and can accurately predict human actions (average angular difference = 24°). Furthermore, with two variables per objective (reward and discount factor), a virtual agent is able to reproduce long human-like navigation trajectories through the environment. We conclude that modular IRL with learned discount factors could be a powerful model for multi-task sensorimotor behaviors.

Acknowledgement: NIH Grant EY05729 NSF Grant CNS 1624378

61.23, *8:45 am* **Representational Similarity of Actions in the Human Brain** Ayse Saygin[1,2](asaygin@ucsd.edu), Burcu Urgen[1,3], Selen Pehlivan[4]; [1]Department of Cognitive Science, University of California, San Diego, CA, USA, [2]Neurosciences Program, University of California, San Diego, CA, USA, [3]Department of Neuroscience, Universita degli Studi di Parma, Italy, [4]Department of Computer Science, TED University, Ankara, Turkey

In the primate brain, visual perception of actions is supported by a distributed network of regions in occipital, temporal, parietal, and premotor areas. The representational properties of each of the regions involved in visual action processing remain to be specified. Here, we investigated the representational content of these regions using fMRI with representational similarity analyses (RSA), along with computer vision-based modeling of the stimuli. Participants viewed 2-second video clips of three agents performing eight different actions during fMRI scanning. We computed the representational dissimilarity matrices (RDMs) for each brain region of interest, and compared these with two different sets of computational model representations constructed based on visual and semantic attributes. We found that different nodes of the action processing network have different representational properties. Posterior STS, known to be a key visual area for processing body movements and actions, appears to represent high-level visual features such as movement kinematics. As expected based on prior research and theory on mirror neurons, as well as computational models of biological motion perception and action recognition, representations became more abstract higher in the hierarchy; e.g., our results suggest inferior parietal cortex represents aspects such as action category, intention, and target of the action. Taken together with prior theory, empirical work, and computational modeling, we conclude that during visual processing of actions, pSTS pools information from downstream visual areas to compute/represent movement kinematics, which are then passed on to nodes of the action processing network in parietal and frontal regions coding higher-order/semantic aspects.

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61.24, *9:00 am* **Temporal-based responses enhance gain in sensorimotor decision-making** David Aguilar-Lleyda[1,2](aguilarlleyda@gmail.com), Elisabet Tubau[1,2], Joan López-Moliner[1,2]; [1]Department of Cognition, Development and Educational Psychology, University of Barcelona, [2]Institute of Neurosciences, University of Barcelona

Numerous studies claim that optimal decision-makers in sensorimotor tasks use knowledge of both their variability and the task's utility function (how each state of the world relates to a gain). In situations requiring interaction with moving objects, people can base their decision on temporal or spatial information: therefore, utility can be defined either as a function of time or space. We aimed at knowing, in such contexts, to what extent performance depends on the domain of the utility function. Our participants completed one of two conditions. A target which could vary in speed (19.5, 25, 32cm/s) moved toward a line. Participants stopped the target and were rewarded according to the target's temporal (time condition) or spatial (space condition) proximity to the line. Responding after the target crossed the line was penalized. We identified whether response strategies were based on spatial (monitoring the target's position) or temporal (pure velocity) cues. Almost all participants in the space condition displayed a spatial strategy, while participants in the the time condition distributed evenly between temporal and spatial strategies. For both conditions, despite similar mean responses and variability in both strategies, participants using temporal cues were more stable across target speeds, thus winning more than those using spatial cues, who responded more after the line in faster speeds and were more penalized. We suggest that this was caused by the limited resolution of the visual system while tracking the spatial position of a moving object, so spatial uncertainty was larger for faster speeds. Our results show how, in environments with more speed variability, actions based on temporal information may be more adaptive, since it brings stability across different speeds. We also evidence the need to consider possible system constraints underlying response strategies when studying sensorimotor decision-making.

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61.25, *9:15 am* **Updating prior distributions in response to sampled visual information** Laurence Maloney[1,2](ltm1@nyu.edu), Shaoming Wang[1]; [1]Psychology, New York University, [2]Neural Science, New York University

Introduction: Bayesian models of visual perception and action presuppose that the visual system has access to accurate estimates of the probability of future events (priors). We examined how human observers would acquire such priors in a simple visual task with binary outcomes and compared their performance to beta-binomial Bayesian updating, the normative solution for such a task. Observers' successive priors were modeled as beta distributions. Methods: Observers sampled with replacement from visual sources that emitted black or white balls. Each sample was independent of all others and a source could be characterized by its probability p[B] of emitting a black ball. A total of 18 observers observed 50 samples taken one by one from the unknown source. We varied p[B] across subjects to take on values 0.1, …, 0.9. Task: Before drawing each sample, observers estimated p[B] and rated confidence. The dependent measure of greatest importance was the change in the estimates of p[B] from sample n to sample n+1 denoted Δn. Analysis: We assumed that the estimate of p[B] was the mode of the current prior. Then the beta-binomial updating model provided parameter-free predictions of successive estimates of p[B] for each trial as well as Δn. Results: We analyzed each observer's data separately.

We found that observers updated their estimates from trial to trial, roughly following the pattern as the beta-binomial updating model. However, the actual weights observers gave to new information were markedly larger (factor of 2-3) than that predicted by the beta-binomial model with large disagreements between ideal and actual.

61.26, *9:30 am* **Uncoupling choice formation and choice-correlated activity in early visual cortex** Corey Ziemba[1,2](ziemba@cns.nyu.edu), Robbe Goris[3], Eero Simoncelli[1,2], J. Movshon[1]; [1]Center for Neural Science, New York University, [2]Howard Hughes Medical Institute, [3]Center for Perceptual Systems, University of Texas at Austin

Responses of individual task-relevant sensory neurons can predict monkeys' trial-by-trial choices in perceptual decision-making tasks. Choice-correlated activity has been interpreted as evidence that the responses of these neurons are causally linked to perceptual judgements. To test this hypothesis, we studied the responses of neurons in V1 and V2 while two macaque monkeys performed two perceptual discrimination tasks. In the first task, monkeys discriminated fine orientation differences between drifting sinusoidal gratings. Both animals exhibited high behavioral sensitivity, and neuronal sensitivity in both V1 and V2 was high. However, only one animal exhibited significant choice-correlated activity. Surprisingly, this correlation was negative: when a neuron fired more vigorously, the animal was less likely to choose the orientation preferred by that neuron. Moreover, choice-correlated activity emerged late in the trial, and earlier in V2 than in V1. In the second task, monkeys discriminated patches of texture synthesized with varying amounts of higher-order correlations. We previously found that in anesthetized macaques, V2 neurons, but not V1 neurons, were sensitive to these higher-order correlations. Both animals performed with high behavioral sensitivity; neuronal sensitivity was low, though higher in V2 than in V1. We found weak choice-correlated activity in both V1 and V2 in both animals, and the correlation was consistently positive. Choice-correlated activity emerged early in the trial in V2, but late in the trial in V1. Our findings reveal substantial variation in choice-correlated activity across subjects performing the same task, as well as across tasks performed by the same subject. Together, these results suggest that choice-correlated activity in sensory neurons is not a reliable signature of their involvement in perceptual judgments.

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61.27, *9:45 am* **Human intracranial electrophysiology suggests suboptimal calculations underlie perceptual confidence!** Megan Peters[1](peters.megan@gmail.com), Thomas Thesen[2,3], Yoshiaki Ko[4], Brian Maniscalco[5], Chad Carlson[2], Matt Davidson[4], Werner Doyle[2], Ruben Kuzniecky[2], Orrin Devinsky[2], Eric Halgren[3], Hakwan Lau[1,6]; [1]Department of Psychology, University of California, Los Angeles, Los Angeles, California, USA, [2]Comprehensive Epilepsy Center, Department of Neurology, New York University Medical Center, New York, New York, USA, [3]Multimodal Imaging Laboratory, University of California, San Diego, La Jolla, California, USA, [4]Department of Psychology, Columbia University, New York, New York, USA, [5]Neuroscience Institute, New York University, New York, New York, USA, [6]Brain Research Institute, University of California, Los Angeles, Los Angeles, California, USA

Prevailing opinion holds that perceptual decisions and confidence in those decisions depend on the same calculations: both optimally reflect the probability of having made a correct decision. However, recent behavioral reports suggest that confidence computations overemphasize the magnitude of information supporting a decision, while selectively down-weighting evidence for other possible choices. Until now, neurobiological evidence supporting this theory has been lacking. Here we use human ECoG and machine learning techniques to demonstrate that perceptual decisions and confidence rely on separable neural representations in a face/house discrimination task. We then show that confidence overly relies on evidence supporting the decision an observer made, even while decisions themselves reflect the optimal balance of evidence for all choices. These findings suggest confidence may not reflect a direct readout of the probability of being correct. While seemingly suboptimal, this strategy may reflect the inference problem that perceptual systems are evolutionarily optimized to solve.

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Eye Movements: Saccades and Pursuit

Wednesday, May 24, 11:00 - 12:45 pm
Talk Session, Talk Room 1
Moderator: Martin Rolfs

62.11, *11:00 am* **Deep neural network features decoded from fMRI responses to scenes predict eye movements** Thomas O'Connell[1](thomas.oconnell@yale.edu), Marvin Chun[1,2]; [1]Department of Psychology, Yale University, [2]Department of Neuroscience, Yale School of Medicine

Neural representations in visually responsive brain regions are predicted well by features within deep hierarchical convolutional neural networks (HCNN's) trained for visual recognition (Yamins et al. 2014, Khaligh-Razavi & Kriegeskorte 2014, Cichy et al. 2016). Additionally, salience maps derived from HCNN-features produce state-of-the-art prediction of human eye movements in natural images (Kümmerer et al. 2015, Kümmerer et al. 2016). Thus, we explored whether HCNN models might support representation of spatial attention in the human brain. We computed salience maps from HCNN features reconstructed from functional magnetic resonance imagining (fMRI) activity and then tested whether these fMRI-decoded salience maps predicted eye movements. We measured brain activity evoked by natural scenes using fMRI while participants (N=5) completed an old/new continuous recognition task and in a separate session measured eye movements for the same natural scenes. Partial least squares regression (PLSR) was then used to reconstruct from BOLD activity features derived from five layers of the VGG-19 network trained for scene-recognition (Simonyan & Zisserman 2015, Zhou et al. 2016). Spatial activity in the reconstructed VGG-features was then averaged across channels (filters) within each layer and across all layers to compute an fMRI-decoded salience map for each image. Group-average fMRI-decoded salience maps from regions in occipital, temporal, and parietal cortex predicted eye movements ($p < 0.001$) from an independent group of observers (O'Connell & Walther 2015). Within-participant prediction of eye movements was significant for fMRI-decoded salience maps from V2 ($p < 0.05$). These results show that representation of spatial attention priority in the brain may be supported by features similar to those found in HCNN models. Our findings also suggest a new method for evaluating the biological plausibility of computational salience models.

62.12, *11:15 am* **Object motion thresholds are amplitude-contingent and tuned to specifically eliminate retinal motion produced by saccades** Martin Rolfs[1,2](martin.rolfs@hu-berlin.de), Sven Ohl[1,2], Richard Schweitzer[1,2,3], Éric Castet[4], Tamara Watson[5]; [1]Bernstein Center for Computational Neuroscience Berlin, Germany, [2]Department of Psychology, Humboldt-Universität zu Berlin, Germany, [3]Berlin School of Mind and Brain, Humboldt-Universität zu Berlin, Germany, [4]Laboratoire de Psychologie Cognitive, CNRS & Aix-Marseille Université, France, [5]School of Social Sciences & Psychology, Western Sydney University, Australia

During saccadic eye movements, objects routinely move across the retina at high speeds but we hardly ever see motion. Here, we present data suggesting that the upper threshold for conscious retinal motion perception may in fact be set specifically to eliminate velocities created by saccades. Using a high-speed projection system with sub-millisecond temporal resolution, we determined velocity thresholds for objects that moved across the retina at the speed of saccades. Upon fixation at the center of the screen, a vertical Gabor stimulus (spatial frequency: 1 cycle per degree of visual angle, dva) appeared either left or right, quickly ramping up to full contrast. The stimulus then moved rapidly in a slightly arched trajectory towards the other side of fixation. Observers performed a curvature discrimination task, judging whether the stimulus passed above or below fixation. We varied the movement amplitude between 4 and 12 dva, in steps of 2 dva. In Experiment 1, the stimulus' horizontal motion followed the velocity profile typical for a saccade of the given amplitude (van Opstal & van Gisbergen, 1987).

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In Experiment 2, its motion was constant (peak velocity for that saccade amplitude). Across trials, we slowed down or accelerated this velocity profile by factors between 0.25 to 2 (resulting in velocities between 48 and 708 dva/s). For each movement amplitude, there was a threshold speed where the percept changed from continuous motion (high performance) to apparent motion (curvature could no longer be judged). Importantly, this velocity threshold was not fixed, but depended on the movement amplitude. Indeed, the relation between velocity threshold and movement amplitude mirrored the main sequence—the relation between saccade amplitudes and their peak velocity. Conscious perception thus settles on a fine compromise that ensures sensitivity to objects moving at high-speeds while eliminating motion consistent with saccadic eye movements

Acknowledgement: Deutsche Forschungsgemeinschaft DFG (grant RO3579/2-1) , German Academic Exchange Service DAAD

62.13, *11:30 am* **Probing saccadic suppression of displacement with reverse correlation.** Eva Joosten[1,2](pointer1313@gmail.com), Thérèse Collins[1,2]; [1]Université Paris Descartes, Sorbonne Paris Cité, Paris, France , [2]CNRS (Laboratoire Psychologie de la Perception, UMR 8242), Paris, France

Each saccadic eye movement changes the retinal signal. We perceive the world as stable. The classical explanation for visual stability is that information about the eye movement is combined with feedback to discount self-induced retinal signals. We applied classification image (CI) analysis to investigate saccadic suppression of displacement (SSD). We compared CIs with the motor behaviur of the eye. We tested 5 observers who reported the location (left or right) of a pre-saccadic stimulus (a small square embedded in noise). During saccade execution, the noise matrix refreshed and the target stepped horizontally backward or forward. Observers reported the direction of the trans-saccadic target step. We compared CIs from peripheral (Figures 1A-B) and foveal tasks (Figures 1D-E), landing errors of primary and secondary saccades (Figures 1C and 1F). Peripheral perceptual CIs were indistinguishable from saccadic CIs. In the foveal task, perceptual responses required less target signal than saccades (Figure 2A) and a strong saccadic bias was observed towards backward target steps (Figure 2B). Furthermore, we found a spatially similar distortion in perceptual CIs and landing positions of the corrective saccades. The distortion is stronger for backward than forward eye movements (Figure 2C). We discuss that visual stability arises from an interplay between the efference copy and a prior believe of stability (e.g. step was not caused by an internal error). When the post-saccadic target position falls within an elliptic region equivalent to saccadic variability (Figure 1C), perceptual CIs and landing positions of secondary saccades display a similar distortion (center of mass shifts away from target), stability is assumed. Outside this region, as with forward steps, displacements are noticed and positions are remapped.

62.14, *11:45 am* **Intra-saccadic localisation is consistently carried out in world-centered coordinates** Tamara Watson[1](t.watson@westernsydney.edu.au), Richard Schweitzer[2,3,4], Eric Castet[5], Sven Ohl[2,3], Martin Rolfs[2,3]; [1]School of Social Sciences & Psychology, Western Sydney University, [2]Bernstein Center for Computational Neuroscience Berlin, [3]Department of Psychology, Humboldt-Universität zu Berlin, [4]Berlin School of Mind and Brain, Humboldt-Universität zu Berlin, [5]Laboratoire de Psychologie Cognitive, CNRS & Aix-Marseille Université

Visual processing and visual perception are both thought to be tremendously depleted during saccadic eye movements. Using a projection system with sub-millisecond temporal resolution we rendered stimuli briefly visible during saccades and tested whether intra-saccadic localisation depends on retina-centered (retinotopic) or world-centered (spatiotopic) coordinates. Participants carried out large saccades in one of eight directions. After the cue to saccade, as indicated by the disappearance of the fixation markers, a stimulus was introduced that was invisible at fixation but visible during the saccade. This was achieved by drifting a Gabor within a stationary envelope in the direction of the eye movement and at a speed equal to the average peak velocity of the participant's own saccades (measured in a separate session). As a consequence of this manipulation, the grating would become stationary on the retina when the eyes were in mid-flight. The stimulus was extinguished at the end of the cued saccade. Participants either immediately made a second saccade to the perceived location of the stimulus or they used a mouse pointer to indicate the stimulus location. We found clear evidence that participants based their localisations unequivocally on spatiotopic coordinates—they indicated the actual location of the stimulus on the screen and were not influenced by the location the stimulus on the retina when it became visible during the saccade. Localisation performance was largely accurate to within one degree of visual angle, irrespective of whether participants made a saccade or used the mouse to indicate the location of the stimulus. The ability to access the world-centered location of purely intra-saccadic stimuli suggests that the position of the eye is accessible with high temporal and spatial fidelity, and readily used for perception and motor control.

Acknowledgement: Universities Australia - German Academic Exchange Service DAAD Deutsche Forschungsgemeinschaft DFG (RO3579/2-1)

62.15, *12:00 pm* **Saccadic curvature is gradually modulated by the direction and amplitude of other saccades in a sequence** Reza Azadi[1](r.azadi9@gmail.com), Robert McPeek[1]; [1]Graduate Center for Vision Research, SUNY College of Optometry, New York, New York, United States

Although saccades are quite fast and accurate, often their trajectories are not completely straight. Previously we showed that saccades curve away from preceding and following saccades when they are executed as a sequence. However, in those experiments, subjects were instructed to execute two perpendicular saccades. In the present study we binocularly recorded eye-movements in a free viewing search task to asses more natural, voluntary saccade sequences with a wider range of angles and amplitudes. In each trial eight targets (0.8° diameter rings) were presented in random positions and subjects were instructed to find a 0.15° horizontal line, located at the center of one of the targets. For this reason, they needed to foveate the center of the targets one by one. Analysis of saccadic curvature revealed that saccades curved away from their preceding and following saccades. We found a sinusoidal relationship between the angle of two consecutive saccades and their curvature: curvature was maximal when the two saccade vectors were perpendicular, and gradually declined as the angle between the vectors became more acute or obtuse. Moreover saccadic curvature was also modulated by the square root of the amplitude of the preceding and following saccades. Interestingly, saccade curvature was affected not only by the immediately preceding and following movements, but also, to a lesser extent, by movements that were more distant in the sequence. Our results show that for a saccade in a gaze sequence, curvature is systematically influenced by the direction and amplitude of the preceding and following saccades. This effect is strongest for the immediately preceding and following movements. These findings reveal that sequential free viewing saccades are not independent from each other, and are consistent with the idea that sequential saccades are processed concurrently in the oculomotor system.

62.16, *12:15 pm* **Cooperative interactions between saccadic and pursuit planning when targeting a moving object** Matteo Lisi[1,2](matteo.lisi@parisdescartes.fr), Patrick Cavanagh[1,2,3]; [1]CNRS, Laboratoire Psychologie de la Perception, UMR 8242, [2]Université Paris Descartes, Sorbonne Paris Cité, [3]Dartmouth College, Psychological and Brain Sciences

When an object of interest moves we use a combination of smooth pursuit and saccadic eye movement to stabilize its image on our retinae and keep it within the region of high visual acuity near the fovea. In this study we investigated the cooperative interactions between saccadic and pursuit eye movements. We asked human observers to intercept and track with their gaze a target moving around a circular trajectory centered on the initial fixation. In our paradigm the eccentricity of the target does not increase as it moves, hence the accuracy by which the first catch-up saccade compensates its velocity is not confounded by the typical saccadic amplitude undershoot (Becker & Fuchs, 1969). Saccade directions revealed, on average, a perfect compensation of target velocity, even when multiple target speeds were interleaved within the same block, and in many cases the saccade landed ahead of the target, anticipating its upcoming displacement. After the first saccade, the speed of the pursuit in the open-loop interval (from 20 to 80ms after saccade landing) was negatively correlated, both on a trial-by-trial basis and across observers, with the saccade direction error: the more the saccade was directed ahead of the target, the slower the speed of the pursuit. Since online visual information cannot modulate pursuit speed during initiation (Lisberger, 2010), this modulation of post-saccadic pursuit must originate from information gathered before the saccade. Taken together these findings indicate that 1) interceptive saccades are guided by a prediction about where the target will be at the time of saccade completion, and 2) the pursuit system uses the error between this extrapolated position and the expected saccade landing to optimize the initial open-loop pursuit after the saccade.

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62.17, *12:30 pm* **Attention is allocated closely ahead of the target during smooth pursuit eye movements: evidence from EEG frequency tagging** Jing Chen[1](Jing.Chen@psychol.uni-giessen.de), Matteo Valsecchi[1], Karl Gegenfurtner[1]; [1]Department of General Psychology, Justus-Liebig-University Giessen

It is under debate whether attention during smooth pursuit is centered right on the pursuit target or allocated preferentially ahead of it. Attentional deployment was previously probed using a secondary task on top of the execution of smooth pursuit, which might have altered attention allocation and led to inconsistent findings. We measured frequency-tagged steady-state visual invoked potentials (SSVEP) to measure attention allocation in the absence of any secondary probing task. Twelve observers pursued a moving dot while stimuli flickering at different frequencies were presented simultaneously at two locations ahead or behind the pursuit target. We observed a significant increase in EEG power (9.1%, Cohen's dz = 0.90) at the flicker frequency of the stimulus in front of the pursuit target, compared to that at the frequency of the stimulus behind. When testing many different locations in a second experiment (N = 12), we found that the enhancement was detectable up to about 1.5º ahead during pursuit (9.0%, Cohen's dz = 0.89), but vanished at 3.5º. In a control condition using attentional cueing during fixation, we did observe an enhanced SSVEP response to stimuli at this eccentricity, indicating that the focus of attention during pursuit is narrower than allowed for by the resolution of the attentional system. Overall, we showed that attention is allocated closely ahead of the pursuit target during smooth pursuit. EEG frequency tagging seems to be a powerful technique allowing investigating attention/perception implicitly when an overt task would be disruptive.

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Visual Memory: Capacity and Integration

Wednesday, May 24, 11:00 - 12:45 pm
Talk Session, Talk Room 2
Moderator: Timothy Brady

62.21, *11:00 am* **Drift, not decay, in neural population activity causes working memory to deteriorate over time** Sebastian Schneegans[1](ss2361@cam.ac.uk), Paul Bays[1]; [1]Department of Psychology, University of Cambridge

Why do working memories become less precise the longer they are maintained? Neural models of visual working memory typically assume that simple visual features are memorized through sustained spiking activity in neural populations. The decrease in recall precision observed with increasing number of memorized items can be accounted for within these models by normalization of total spiking activity, resulting in fewer spikes contributing to the representation of each individual item. Longer retention intervals likewise reduce recall precision, but it is unknown what changes in population activity produce this effect. One possible explanation is that spiking activity decays over time, such that the same mechanism (decreased spike rate for each item) accounts for both the effect of set size and retention duration. Alternatively, reduced performance may be caused by drift in the population activity over time due to random noise in recurrent connections, without decrease in overall spiking activity. To distinguish between these hypotheses, we presented subjects with memory displays containing one to four differently-colored discs arranged around a central fixation point. After a variable delay, one of the colors was shown as a cue and subjects had to make a saccade to the memorized location of that item. Based on an integrator model of decision making, we would predict a fixed relationship between response latency and recall precision across conditions if the effects of set size and retention duration are both caused by decreased spiking activity for each item. In contrast, the drift hypothesis predicts no systematic changes in latency with increasing delays. Our results show both an increase in latency with set size, and a decrease in response precision with longer delays within each set size, but no systematic increase in latency for increasing delay durations. We conclude that working memories drift rather than decay with time.

Acknowledgement: Wellcome Trust

62.22, *11:15 am* **Beyond the magic number four: Remapping high-capacity, pre-attentive, fragile working memory.** Paul Zerr[1](p.zerr@uu.nl), Surya Gayet[1], Kees Mulder[2], Ilja Sligte[3], Stefan Van der Stigchel[1]; [1]Experimental Psychology, Helmholtz Institute, Utrecht University, The Netherlands, [2]Methodology and Statistics, Utrecht University, The Netherlands, [3]Cognitive Neuroscience Group, Department of Psychology, University of Amsterdam, The Netherlands

Visual short term memory allows us to access visual information after termination of its retinal input. Generally, a distinction is made between a robust, capacity-limited form (working memory, WM) and high-capacity, pre-attentive, maskable forms (sensory memory, e.g. fragile memory, FM). Eye movements pose a challenge for spatial memory because retinotopically coded coordinates need to be updated with every saccade (spatial remapping). This computationally intense process has been considered strictly limited to WM. To answer the question whether fragile, pre-attentive memory items are also remapped we directly compared trans-saccadic WM (tWM) and FM (tWM) capacity. Participants memorized oriented bars and reported on a change in probe displays after making a saccade. A predictive retro-cue indicated future targets and protected FM from being masked by the memory probe, which is known to increase capacity estimates due to the inclusion of FM items (retro-cue benefit). If only stable, attended memory items can be remapped, then capacity after a saccade should be that of tWM, even if capacity was high before the saccade (FM). We found that tFM capacity was considerably higher than tWM capacity. This demonstrates that in addition to attended items in WM, non-attended items in FM were also remapped. In a second experiment, we retroactively masked items to disrupt the retro-cue benefit. The results show that masks at the retinotopic location as well as at the spatiotopic location reduced the retro-cue benefit. This confirms that FM items have been remapped to task-relevant, world-centered coordinates. We provide conclusive evidence for the existence of high-capacity, trans-saccadic, fragile visual memory and challenge the strongly held belief that trans-saccadic memory is identical to robust WM. This has important implications for our understanding of spatial remapping, which is thought to be intimately linked to spatial attention. Our results demonstrate that un-attended items can also be remapped.

Acknowledgement: This research was funded by a VIDI Grant 45213008 from the Netherlands Organization for Scientific research to SVdS.

62.23, *11:30 am* **Visual working memory resetting is triggered by a loss of objects-to-representations correspondence** Halely Balaban[1,2](halelyba@mail.tau.ac.il), Trafton Drew[3], Roy Luria[1,2]; [1]Sagol School of Neuroscience, Tel Aviv University, [2]The School of Psychological Sciences, Tel Aviv University, [3]Psychology Department, University of Utah

Visual working memory (VWM) representations are modified when the represented items change. This updating process relies on an ongoing correspondence between each VWM-representation and a specific object in the environment, thereby enabling access to the correct representation. Importantly, we argue that when this correspondence breaks, VWM cannot update, and must instead reset: discard the existing representations and start anew. We aimed to establish the loss of the objects-to-representations mapping as a necessary and sufficient condition for the resetting process, by demonstrating that when (and only when) this mapping breaks, VWM will reset. First, we demonstrate that similar manipulations trigger either resetting or updating, depending on whether the correspondence could be maintained. In a shape change-detection paradigm, we presented black polygons that moved and could separate into halves. The movement was task-irrelevant, but established a correspondence between the moving polygon and a single representation. The separation broke the correspondence, because afterwards VWM had to track each half independently (requiring two correspondences), triggering a resetting process. The contralateral delay activity, an electrophysiological marker whose amplitude rises as more items are held in VWM, sharply dropped, indicating a loss of VWM-contents. Conversely, when the pre-separation correspondence supported a separate mapping for each half (by presenting each in a dif-

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ferent, task-irrelevant, color), VWM could maintain the mapping during the separation, resulting in updating instead of resetting. Second, using behavioral measures we demonstrate that VWM is blind to salient changes occurring during resetting: when the shape of a moving polygon changed concurrently with its separation (i.e., during resetting), subjects missed this change. This is presumably because the representations cannot be accessed, since there is no valid correspondence. Critically, we demonstrate that the effect is limited only to the item whose correspondence is broken, while similar changes in a nearby unseparated polygon were easily detected.

62.24, *11:45 am* **Proactive interference results from visual working memory, not just contamination from visual long-term memory** Timothy Brady[1](timbrady@ucsd.edu); [1]Department of Psychology, University of California San Diego

Visual working memory (VWM) is our mental chalkboard: We can hold visual images actively in mind, and then, when we are done, erase them. But are the items we previously held in VWM ever truly erased, or do they, like a real chalkboard, leave behind smudges that interfere with subsequent memories? Some work has claimed to find effects of previously held items in VWM tasks, but these results are controversial because they could derive from participants making use of not only VWM, but also long-term memory (VLTM). Here we examined proactive interference in VWM for colors by using a paradigm designed to isolate the influence of VWM vs. VLTM traces. Participants (N=50) were shown 4 outlines of circles, which were briefly filled in with colors. Then the circles rotated such that each outline was now one spot clockwise or counterclockwise from where it began, and participants reported what color would now be in a particular cued location by choosing from a set of 7 options. Two of the answer choices always corresponded to colors that had (1) been originally shown in the tested location on the previous trial (proactive-before-rotation), and (2) ended up in the tested location on the previous trial in VWM (proactive-rotated). Because participants never saw the items in their updated locations, and had to actively manipulate them, we reasoned that any interference from the previous trials' updated locations must derive from VWM, not VLTM. We found the largest interference effects were those with a VWM locus: participants incorrectly picked the proactive-rotated color more than a color that had not appeared on the previous or current trial (6.5% vs. 5.8%; p=0.04). We replicated this effect again in a new sample (N=40; p=0.025). This suggests that VWM is not truly erased between trials, even in color working memory.

62.25, *12:00 pm* **Finding maximal and minimal elements in a set is capacity-unlimited and massively-parallel** Edwina Picon[1](edwinap@gmail.com), Darko Odic[1]; [1]University of British Columbia

Traditional accounts of working memory are divided into two irreconcilable camps: memory is either thought to be capacity-limited to 3 – 4 items, or to be resource-limited as the number of items grows. Here, we show that certain computations – namely identifying the maximal and minimal element along a dimension such as length – is neither capacity- nor resource-limited: i.e., finding the maximal or minimal element in a scene is automatic, efficient, and effortless. In three separate experiments, observers are shown 5 – 7 colored lines on the screen (e.g., a blue, a yellow, a green, a purple, a red, a black, a white) for 1200 milliseconds. In Experiment 1 (N = 40), participants are asked to either perform a pairwise comparison (e.g., "Is the blue line longer than the yellow line?") or a maximal comparison (e.g., "Is the blue line the longest?"), thereby requiring them to attend, remember, and compare all seven lines. We find that the maximal comparison is faster and more accurate that the pairwise comparison, even though the computation requires the representation of all lines (Fig1). In Experiment 2 (N = 80), participants identify the color of a particular line in the sequence (e.g., "Which line is the second longest?"). We find a pronounced advantage in accuracy and RT for identifying the longest and shortest lines, with an increasing, serial cost to each successive line in the sequence (Fig2). Finally, we replicate these effects developmentally and find that the identification of the maximal element is easier compared to pairwise from at least age 2 onward. These results suggest that the computations supporting the identification of the maximal element are distinct and more efficient than those supporting the identification and comparison of only two items, providing a challenge to traditional views of working memory capacity limits.

62.26, *12:15 pm* **Building the unexpected: scene grammar shapes the way we interact with objects, strengthens spatial representations, and speeds search.** Dejan Draschkow[1](draschkow@psych.uni-frankfurt.de), Melissa Vo[1]; [1]Scene Grammar Lab, Goethe University Frankfurt

General scene knowledge (our "scene grammar") and episodic memory play an important role in guiding search and navigation. In two virtual reality experiments we investigated the influence of scene syntax on participants' interactions with objects and the detail of spatial memory representations formed during these interactions. In Experiment 1 (N = 9), participants had to arrange virtual objects consecutively in sixteen rooms. In half of the rooms participants were instructed to arrange objects in a syntactically meaningful way (e. g. placing a pot onto a stove), whereas in the other rooms the objects had to be arranged chaotically. In a subsequent, unannounced free recall, task location memory was assessed by asking participants to rebuild these rooms. Explicit location memory was better for syntactically consistent compared to inconsistently placed objects. The instruction to place objects inconsistently lead to a longer interaction time with objects – measured as object grabbing time. This was especially prominent for small (local) objects. Large (global) objects were placed earlier in the trial than local objects. In Experiment 2 (N = 8), participants had to build eight rooms in the same fashion as in Experiment 1, yet this time a surprise search task followed. Participants either searched for objects within the rooms they had built, or within rooms arranged by participants from Experiment 1. Search was speeded for consistently placed objects, especially for objects placed by participants themselves. Additionally, more distance was covered to find objects in inconsistent rooms, most prominently when arranged by somebody else. Together, these results suggest that contextual violations, even when self-inflicted, lead to differential object-interaction behavior, as well as a decrease in memory performance. Real-world search profits from a meaningful arrangement of objects both in self-generated as well as unknown contexts by reducing the effort to move the body to find the target.

Acknowledgement: DFG grant VO 1683/2-1 to MLV

62.27, *12:30 pm* **Mechanisms of Visual Working Memory Manipulation: When "Bird-Brain" is a Compliment** Irene Pepperberg[1](impepper@media.mit.edu), Hrag Pailian[1]; [1]Department of Psychology, Harvard University

The abilities to store and manipulate information in visual working memory (VWM) stand at the cornerstone of intelligent behavior. Demonstration of a 3-4-item storage limit in humans and other species implies a homologous storage mechanism. In contrast, evolutionary bases underlying VWM manipulation remain unexplored. Here, we use a task akin to the "Shell Game" to examine whether the ability to manipulate information is uniquely human. We compared humans' performance on a computerized version of this task with that of a Grey Parrot on a live version adapted for animal testing, administered by a human experimenter. In both tasks, a varying set size (2-4) of colored objects was presented briefly, after which objects were covered by occluders. Occluders either remained stationary (storage: 0 swaps) or pairs of occluders swapped positions a number of times (manipulation: 1-4 swaps). A target color was subsequently presented and participants had to indicate the location of the cued color. Whereas storage trials require only that color-location bindings be stored in VWM, manipulation trials additionally require that these bindings be updated as objects swap positions. Performance accuracy on storage trials exhibited by humans and the parrot were both consistent with a 3-4 –item storage limit; the parrot was also perfect on 5 (humans not tested). Manipulation-related performance was near ceiling for both groups on set size 2 trials. However, humans experienced a systematic decrease in accuracy as swaps increased for set sizes 3 and 4. Interestingly, the parrot generally remained near ceiling for all set size 3 dynamic trials, but experienced catastrophic failure for set size 4 at three swaps. These results suggest that VWM manipulation is not unique to humans, inviting further investigations into whether VWM manipulation is supported by common vs. separate mechanisms across species, and whether differences exist for computer-based vs. live trials.

Acknowledgement: The Alex Foundation

WEDNESDAY MORNING POSTERS

ATTENTION: REWARD AND VALUE

Wednesday, May 24, 8:30 am - 12:30 pm
Poster Session, Pavilion

63.4001 **Reward modulates cross-modal conflict** Guanlan Kang[1,2](kangguanlan_33@163.com), Wenshuo Chang[1,2], Xiaolin Zhou[1,2,3,4,5]; [1]Center for Brain and Cognitive Sciences, Peking University, Beijing 100871, China, [2]School of Psychological and Cognitive Sciences, Peking University, Beijing 100871, China, [3]Beijing Key Laboratory of Behavior and Mental Health, Peking University, Beijing 100871, China, [4]Key Laboratory of Machine Perception (Ministry of Education), Peking University, Beijing 100871, China, [5]PKU-IDG/McGovern Institute for Brain Research, Peking University, Beijing 100871, China

Cross-modal conflict arises when information from different sensory modalities are incompatible with each other. Such conflict may influence the processing of stimuli in the task-relevant modality (and call for cognitive control to resolve this conflict). Here we investigate how reward modulates cross-modal conflict control during object categorization by manipulating reward (reward vs. no-reward) and stimuli type (visual-only vs. audio-visual congruent vs. audio-visual incongruent). In visual-only condition, only images of objects were presented. In audio-visual conditions, images of objects and sounds commonly associated with specific objects were presented simultaneously, with the image and the sound either congruent (associated with the same object) or incongruent (associated with different objects). Participants were instructed to categorize the images (animate/inanimate) and ignore the sounds while their brain activities were recorded by EEG. At the beginning of each block, a cue was presented indicating reward availability of that block. In a reward block, correct responses with RT faster than the baseline RT (mean RT of the practice trials) were rewarded, whereas in no-reward block no reward was delivered irrespective of performance. Behaviorally, reward facilitated performance in a stimuli type-dependent manner: in no-reward conditions, RTs were shorter for congruent trials than for incongruent trials; this difference was absent in reward conditions. Neurally, we found that the fronto-central N2 (240-320 ms) was larger in the incongruent condition than in the congruent condition, but only when there was no reward for performance. Time-frequency analysis revealed a conflict-related modulation of the non-phase-locked theta power over the fronto-central sites, but again, only for no-reward conditions. Taken together, our results demonstrate that reward modulates cross-modal conflict resolution and the conflict-related N2 and theta-band neural oscillations.

63.4002 **Perceptual salience of self-relevant information in shared environments** Katie Jones[1](k.jones.2@warwick.ac.uk), Melina Kunar[1], Derrick Watson[1]; [1]Department of Psychology, University of Warwick

Attributing personal significance to otherwise neutral stimuli has been demonstrated to modulate perceptual processing (Sui, He & Humphreys, 2012). In shared environments it is particularly pertinent that individuals can identify and prioritize self-relevant information over information relevant to others. However, studies of joint-task performance have suggested that co-actors automatically form cognitive representations of each other's task rules, resulting in task interference. To determine if participants are able to successfully prioritize self-relevant information in shared tasks we asked pairs of co-actors to perform a joint perceptual matching task when they were seated side-by-side. Each participant associated three geometric shapes with either the self, the co-actor, or an imagined stranger. In Experiment 1 both participants were assigned the same shape-label associations (e.g. self-triangle, partner-circle, stranger-square). In Experiment 2 participants were assigned different shape-label pairings for self and partner associations (e.g. Participant A: self-triangle, partner-circle, stranger-square; Participant B: self-circle, partner-triangle stranger-square). Participants then judged independently whether presented shape-label pairings were correctly matched. No difference was found between the experiments, ruling out interference relating to task co-representation. The data revealed a reliable self-benefit, both in terms of response times and perceptual sensitivity. Interestingly, participants were slower to identify an incorrect match when the self-associated shape was paired with the label 'partner' than when paired with the label 'stranger'. This finding indicates that there may be a conceptual overlap between representations of the self and a co-actor, resulting in a difficulty in exerting self-other control when both representations are activated. Our study shows that while people in shared tasks demonstrate a reliable perceptual bias for self-relevant information, they also experience greater difficulty discriminating between self- and other-relevant information when the 'other' is a present co-actor.

Acknowledgement: ESRC

63.4003 **Adaptation and stress independently influence the emotional categorization of facial expressions** Alex Terpstra[1](alexander.terpstra@psych.ubc.ca), Mana Ehlers[1], Rebecca Todd[1]; [1]University of British Columbia

Introduction: Visual after-effects, in which repeated exposure to one category of visual stimulus tunes perception such that an ambiguous stimulus looks more like the opposite category, have been observed for facial emotion. For example, ambiguous facial expressions are categorized as more positive with repeated exposure to unambiguously angry facial expressions. While previous research has documented effects of stress on visual processing of facial emotion, the influence of stress on emotion adaptation effects is not known. Thus, the goal of the present study was to examine effects of acute stress on shifts in biases in categorization of facial expressions as happy or angry elicited by visual adaptation. Methods: 226 healthy young adults were assigned to either a stress condition (n=111), in which a socially evaluated cold-pressor test was administered, or a matched control condition (n=115). In a bias-probe task presented before and after adaptation, faces morphed to create a continuum of 15 frames ranging from unambiguously angry to unambiguously happy were presented in random order. Participants were asked to make forced-choice judgments of whether each facial expression presented was happy or angry. To generate adaptation effects we employed a 2-back task, in which participants were presented with a series of unambiguously angry faces and asked to indicate whether each face had appeared two frames earlier. Manipulation checks were also conducted. Results: A repeated measures ANOVA revealed a shift towards categorizing a higher proportion of faces as happy post-adaptation. Although there was an overall lower tendency to categorize unambiguously angry faces as angry under stress, there was no effect of stress on adaptation effects. Conclusion: This study provides further evidence that interpretation of facial expressions can be manipulated using adaptation. The presence of acute stress may not have a significant influence on changes in patterns of categorization bias with adaptation.

Acknowledgement: Canadian Institutes of Health Research

63.4004 **Spatial and feature-based attention to emotional faces** David De Vito[1](ddevito@uoguelph.ca), Cody Cushing[2], Hee Yeom Im[2], Reginald Adams, Jr.[3], Kestutis Kveraga[2]; [1]Department of Psychology, University of Guelph, [2]Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, [3]Department of Psychology, The Pennsylvania State University

Anticipation enhances our ability to adaptively respond to positive and negative stimuli. However, research is quite mixed about how different types of expectations affect response efficiency. Specifically, we examined how cueing stimulus location (spatial attention) and/or emotion (feature-based attention) affects response efficiency on a trial-by-trial basis. Our task engaged participants (N=44) in speeded identification of emotion expressions (angry versus happy) that were presented peripherally (left versus right) for 250 ms. Prior to face onset, colored arrow cues, which were 95% predictive, were displayed for 1 s to inform subjects of either stimulus location or emotion, both, or neither (Uncued). Overall, responses to happy faces and expressions presented in the right visual field yielded shorter reaction times (RTs), but the RTs, accuracy, and response patterns were strongly modulated by cueing condition. Uncued trials elicited the longest RTs (average: 615 ms). Cueing location produced faster (average: 578 ms) and more accurate responses than uninformative cues ($p< .001$), while cueing emotion resulted in even shorter RTs (average: 546 ms) than cueing

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location (p< .001). Cueing both location and emotion (p< .001) evoked fastest responses (average: 481 ms), in a superadditive function reflecting the combined effects conferred by cueing emotion and location (p < .001) separately. Moreover, the face identity cues (gender and race) interacted with cueing. On Uncued trials or when only the location was cued, we found emotion x gender (faster for happy female and angry male), emotion x race (faster for angry black and happy white faces), as well as emotion x gender x race interactions, which were abolished by emotion cueing. In conclusion, we found that being able to anticipate facial emotion and location substantially speeds up recognition, while interactions with facial identity cues (race and gender) are abolished by emotion cueing.

Acknowledgement: R01 MH101194

63.4005 Irrelevant social status cues drive visual attention Barry Giesbrecht[1,2,3](giesbrecht@psych.ucsb.edu), Matthias Gobel[4], Mary MacLean[1,2]; [1]Psychological and Brain Sciences, UC Santa Barbara, [2]Institute for Collaborative Biotechnologies, UC Santa Barbara, [3]Interdepartmental Graduate Program in Dynamical Neuroscience, UC Santa Barbara, [4]SAGE Center for the Study of the Mind, UC Santa Barbara

The value of information appears to determine attentional priority. Attention is biased more strongly towards visual cues associated with larger rewards than those associated with smaller rewards – indicating that the learned value differential affects priority. We investigated whether another value differential, social status, would similarly affect attention. Specifically, we tested whether the learned value of non-informative cues associated with the gaze of either a high status or low status partner would drive attention. Participants (n = 59) completed a visual search task synchronously in groups of three. For each participant one "partner" was designated as high status, the other was designated as low status using a deceptive manipulation prior to the task. During the task participants were presented with a pre-target cue at either the target (valid cue) or distracter location (invalid cue). After target presentation participants received feedback about whether the cue had indicated the gaze of the high status partner, the low status partner, or was randomly selected by the computer (PC). The color of the cue differed according to gaze condition (high, low, or PC). Cueing effects (valid vs. invalid RT) interacted significantly with gaze condition (p = .026). A reliable cueing effect (p < .001) was observed for the high status cue, but not the low status (p = .055) or PC cues (p = .371). These effects were similar for both the 50 and 500 ms cue-target SOAs, indicating that the effects were automatic but not subject to IOR. Reliable cueing effects (p < .001) were observed with the same cue stimuli when presented again in a non-social setting at a later date, but were no longer modulated by gaze condition (p = .893). Our results indicate that much like reward, irrelevant, non-informative social value information can contribute to value-driven attention.

Acknowledgement: Army Research Office contract W911NF-09-0001

63.4006 Emotional pictures automatically capture attention Minwoo Kim[1](mkim@psych.udel.edu), Matt Taylor[1], James Hoffman[1]; [1]Department of Psychology & Brain Sciences, College of Arts & Sciences, University of Delaware

Emotional stimuli rapidly grab our attention even when we are deeply engrossed in other activities. For example, the presentation of a task-irrelevant picture interferes with the detection of closely following target picture, a phenomenon known as "emotion-induced blindness" (EIB; Most, Chun, Widders, & Zald, 2005; Kennedy, Rawding, Most, and Hoffman, 2014). Although the occurrence of EIB suggests that emotional pictures automatically capture attention, this paradigm doesn't present a very stringent test of this claim. People are paying attention to the pictures and they have a perceptual set for a target that is different than the background pictures. These features would contribute to capture by the emotional picture. In the current study, we tried to arrange a situation that would favor the ability of ignoring the emotional picture. Participants tracked two target circles moving among four identical non-target circles (multiple object tracking or MOT). A gap could occur in the left or right side of one of the targets and observers had to make a speeded response indicating the gap side. The moving objects appeared in front of a rapidly presented (10/sec.) sequence of pictures that could contain an emotional distractor. We found that tracking accuracy was unaffected by the occurrence of an emotional picture but RT to the appearance of the gap was delayed by 30 msec. when the appearance of the gap coincided with an emotional picture. Attention capture was confirmed by the presence of an N2pc-like ERP component that was elicited by the to-be-ignored emotional picture. In contrast, the N2pc elicited by the gap appearance was delayed by the presentation of the emotional distractor. These results provide additional evidence that emotional pictures automatically capture attention, even when they are never task-relevant and participants are engaged in an attention-demanding primary task.

63.4007 A trade-off between performance and effort in the choice of attentional control settings Jessica Irons[1](irons.39@osu.edu), Andrew Leber[1]; [1]Department of Psychology, The Ohio State University

In real-world visual search, there are often multiple different strategies for controlling attention (e.g., searching for an item's color, shape, or size). Recently we found that when observers are free to choose between different attentional control settings, they often make sub-optimal choices. We attributed this finding to a performance-effort trade-off. Specifically, observers sometimes forgo an optimal but cognitively-demanding setting in favor of one that is less effortful and less effective. However, an alternative explanation is that they simply lack the necessary knowledge to determine the best strategy. To compare accounts, we directly manipulated the motivation to maximize performance by rewarding fast visual search. Participants (N = 48) performed the adaptive choice visual search task, in which they were free to choose between two different search targets. The proportion of target-similar items in the display varied over time, such that the optimal target choice changed periodically. A baseline phase was followed by a reward phase, in which each trial earned a monetary reward based on response speed (performance contingent group), or assigned at random (random reward group). Results showed that the performance contingent group made significantly more optimal choices and were significantly faster in the reward phase compared to baseline. The random reward group showed no such improvement. The findings argue against the view that sub-optimal performance was due to limited knowledge, and show that the choice of attentional control settings is sensitive to the trade-off between effort and reward. Further, they emphasize the importance of considering motivation in developing a greater understanding of goal-directed attentional control.

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63.4008 Can value-driven attentional capture be extinguished? Anne Milner[1](amilner@umail.ucsb.edu), Mary MacLean[1], Barry Giesbrecht[1]; [1]University of California, Santa Barbara

Visual stimuli previously associated with reward can capture attention in the absence of reinforcement (Anderson & Yantis, 2012). We investigated whether reward-associated attentional capture would persist after repeated exposure in the absence of reinforcement or whether the effect could eventually be extinguished. During the training phase, which consisted of 800 trials, participants (n=12) learned to associate one of two target colors (red and blue) with reward, and the other with the absence of reward. One week later, during the extinction phase, participants completed 1600 trials of the same task but were no longer rewarded. Reaction times were significantly faster to reward-associated targets than no reward-associated targets. Critically, there was an interaction between reward condition and task phase such that the difference between rewarded and unrewarded trials was significantly larger during training (MD=50.32ms, SEM=10.8) than extinction (MD=25.08ms, SEM=4.64), suggesting that there was reduction of the reward-associated capture effect during extinction. However, when the analysis was broken down by block, there was an interaction between reward condition and block during training, but not during extinction. This interaction indicates the presence of learning during training, because the difference between rewarded and unrewarded trials increased over the course of the training phase, but not during extinction. These findings suggest that while the effect of value-driven attentional capture is reduced, extinction learning did not occur. However, 7 out of the 12 participants displayed some extinction learning, whereby the difference between previously reward-associated and no reward-associated targets decreased from the first to the last block of the extinction phase. Although there is evidence of a reduction in the effect of value-associated stimuli, the effect still remains statistically significant over 1600 trials, suggesting evidence for some persistence. Thus, reward learning is persistent, but individual differences may play a role in how value-driven attention is learned and extinguished.

Acknowledgement: This work was supported by the Institute for Collaborative Biotechnologies through contract W911NF-09-0001 from the U.S. Army Research Office

63.4009 Color and Shape Feature Dimensions Independently Potentiated in Value-Driven Attentional Capture

Evan Palmer[1](evan.palmer@sjsu.edu), Lindsey Davies[2], Corina Tillman[2]; [1]Department of Psychology, San Jose State University, [2]Department of Psychology, Wichita State University

Observers rewarded for finding color targets in a training task can have their attention captured by those rewarded colors in an oddball shape search, a phenomenon known as value-driven attentional capture (VDAC). In Experiments 1-4 of the current work, observers were rewarded for finding simple shapes (circle and diamond) in the training phase. In the test phase searching for an oddball color target, previously rewarded shapes slowed response times (RTs) when presented as distractors (Experiments 1 and 2) and speeded RTs when presented as targets (Experiments 3 and 4). This VDAC to shapes can overcome oddball targets with weak color contrast (red among orange) but not strong color contrast (red among green). After establishing that VDAC to shapes is possible, we asked whether color by shape conjunction targets can be trained. In Experiment 5, participants were rewarded for finding either red or circle targets in the training phase. In the test phase, they searched for oddball shape and oddball color targets. Circle and red targets both produced faster RTs than non-rewarded shape and color targets. Additionally, red circle conjunction targets (never seen in training) yielded the fastest RTs overall. In Experiment 6, participants were rewarded for finding red circle and green diamond conjunction targets during training. In the test phase, they again searched for oddball shape and oddball color targets. When targets contained a previously rewarded color or shape, RTs were again faster than non-rewarded colors and shapes. Additionally, previously trained conjunction targets yielded faster RTs, as did reverse conjunction targets (red diamonds and green circles). The additive priming of shape and color dimensions, regardless of whether they were trained separately or in conjunction, and regardless of whether they were tested in trained conjunctions or reversed conjunctions, indicates that the shape and color dimensions are independently potentiated in VDAC

63.4010 Performance-contingent reward training modulates reaction time variability, even in the absence of previously rewarded stimuli

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Stimuli previously associated with reward have been shown to slow responses when presented as irrelevant distractors in subsequent, unrewarded tasks (value driven attentional capture, or VDAC). During reward training, participants search for a target (color-defined circle) and discriminate the orientation of a line contained inside. Only correct responses made before a deadline are rewarded. To maximize earnings, participants must consider multiple reward contingencies: responding too quickly increases error rates; missing the response deadline reduces reward probability to zero, whereas responding at chance still yields reward half the time. Does facing these reward contingencies during training alter the way in which participants balance speed and accuracy when reward is removed and the response deadline lengthened (i.e., the VDAC test phase)? Using the VDAC procedure (Anderson et al. 2011, PNAS, Experiment 3, 800ms/1200ms response deadlines in training/test), we randomly assigned 46 participants to receive either performance-contingent reward during training or correct/incorrect feedback only during training and a flat reward. We focus here on distractor-absent test trials to eliminate any value driven attentional confounds. Using maximum likelihood estimation, individual reaction time (RT) distributions were fit with a three parameter, exponentially modified Gaussian function: mu and sigma describe the mean and standard deviation of the Gaussian portion; tau describes the exponential portion, which gives the distribution its characteristic positive skew. Despite the absence of previously rewarded stimuli, participants who received performance-contingent reward during training showed significantly wider RT distributions during test (greater sigma values), relative to the control group. Sigma parameter estimates were also positively correlated with error rates, reflecting a behavioral cost to this increased variability. These data provide preliminary evidence that performance-contingent reward training increases reaction time variability when reward is no longer at stake, even in the absence of previously rewarded stimuli.

63.4011 Feature-based reward learning biases dimensional attention

Jennifer Bu*[1](jbu@princeton.edu), Angela Radulescu*[1], Nicholas Turk-Browne[1], Yael Niv[1]; [1]Department of Psychology and Princeton Neuroscience Institute, Princeton University

Rewards can help teach selective attention what is relevant in a complex world. Previous studies have demonstrated that specific features consistently associated with high reward capture attention more than those associated with low reward. How reward influences attentional capture at the level of entire feature dimensions remains unclear. Here we test the hypothesis that learning to attend to a highly rewarding feature in one dimension results in attentional capture for other unrewarded features within that same dimension, compared to features in other dimensions. Participants viewed a series of stimuli ("tokens") that differed in color and orientation, and "collected" each token via a button press in order to earn its point value. For each block of trials, tokens with one specific feature (e.g., red) provided high reward with 90% probability and low reward with 10% probability. Tokens without this feature provided high reward with 10% probability and low reward with 90% probability. Which feature was rewarded changed on every block. Participants were randomly assigned to either a 'color' group or an 'orientation' group, and all rewarded features were drawn from the corresponding dimension. To probe attention, we occasionally interrupted the token collection task with a visual search task. Each search array contained both a color singleton and an orientation singleton, one of which was randomly chosen each trial to be the search target. We hypothesized that a learned dimensional attention bias would facilitate pop-out and thus search for singleton targets in the dimension containing the highly rewarded feature. Consistent with this hypothesis, the color group had faster response times for color versus orientation singleton targets. No differences were observed for the orientation group. These findings suggest that reward can drive attentional capture at the dimensional level, at least for color.

63.4012 Value-associated Stimuli Bias Ensemble Size Estimates

Daniel Dodgson[1](daniel.b.dodgson@gmail.com), Jane Raymond[1]; [1]School of Psychology, University of Birmingham

After brief exposure to multiple object arrays observers seem able to use summary statistics to make generalized judgments of object attributes. Such ensemble perception is thought to aid visual cognition of complex scenes by overcoming tight capacity limitations through extraction of 'gist'. However, even when a scene is rich with perceptual consistencies, some stimuli within it may have greater motivational salience than others. Previous work from our lab has shown that value-associated stimuli are processed faster and maintained in WM better than neutral stimuli, suggesting that such stimuli may bias ensemble perception. To investigate we asked participants to adjust a response circle to match the average size of 12 heterogeneously sized circles viewed simultaneously for 200 ms (test array). In an initial value-learning phase, all circles had the same color and responses were rewarded with either a high or a low reward depending on array color. In a second test phase, test arrays comprised circles of three different colors and no rewards were forthcoming. On different trials, the smallest four or the largest four circles were presented in the previously high or low reward-associated color. In the first experiment, average size estimates were biased towards the mean size of circles with the high reward-associated color, especially when they comprised the largest circles. This value-biasing effect was not found for low reward-associated colors. To investigate whether this effect occurred late in processing, we repeated the experiment, this time inserting a pattern mask immediately after the test array in test phase trials only. In addition to value-biasing being eliminated, test phase (but not value learning phase) performance accuracy was significantly better than in the first experiment. Our results demonstrate that previously rewarding stimuli bias the extraction of summary statistics and we suggest that such biases result from slow recurrent processes.

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63.4013 Go for information, but remember reward: Motivational and informational value affect the deployment of visual attention

Hanna Kadel[1](kadel@uni-marburg.de), Stephan Koenig[1], Metin Uengoer[1], Anna Schubö[1]; [1]Philipps-University of Marburg, Germany

Visual selective attention is controlled by stimulus properties in a bottom-up manner, by the observer's current intention via top-down mechanisms, and by an observer's prior experience and learning history. In the present electrophysiological study we examined to which extent a stimulus' motivational value (reward) and its informational value (prediction) affect attention deployment. Value associations were manipulated in a categorization learning task, where participants responded to colors that predicted reward with variable reliability. The impact of acquired reward and predictability associations was assessed in an unrelated visual search task, in which irrelevant additional singleton distractors were presented together with a shape target. Distractor colors were similar as in the learning task, but had neither rewarding nor predictive value here. Event-related potentials and behavioral measures showed that during learning, observers' selective attention was mainly guided by informational value (more attention towards predictive than unpredictive stimuli), but was additionally modulated by reward value (more attention towards high reward than low reward stimuli). In the search task, the interference caused by distractors only depended on their reward associations (more attention to high than low reward distractors), regardless of how predictable the reward was during learning. Our findings show that both motivational and informational value affect selective attention, but do so differently dependent on current task requirements. This suggests that different mechanisms might underlie attentional preferences for motivational and informational value.

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63.4014 The Influence of Saliency and Value on Perceptual Averaging.

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Prior work has shown that observers are often poor at providing detailed information concerning the visual properties of a briefly presented stimulus when this stimulus is part of a larger set of stimuli. On the contrary, observers appear to be very capable of reporting on statistical regularities that describe a whole set of stimuli, such as the mean size of a set of circles. Furthermore, there is some evidence that the way an observer perceives such statistical regularities is partially dependent on top-down attention, such that the perceived mean is often biased in the direction of a voluntarily attended stimulus. However, it is unclear to what extent other sources of attentional bias, such as bottom-up and value-driven attention influence how an observer perceives and encodes statistical regularities. To investigate this, we conducted a series of experiments in which an observer was asked to adjust the size of a test circle to the mean size of a previously displayed set of circles that all varied in size. Crucially, we manipulated the saliency and value of one or more members of the set of circles, such that bottom-up and/or value-driven attention would be involuntarily allocated to these circles. Our results show that the way observers perceive statistical regularities is predominantly biased by saliency/bottom-up attention, whereas value-driven attention appears to play a lesser role in this process.

63.4015 Target self-relevance enhances visual search efficiency

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Merely associating one's sense of self with a stimulus enhances speed and accuracy of responses to that stimulus in a label-matching paradigm (Sui, He, & Humphreys, 2012), implying prioritized processing of self-relevant stimuli. However, the precise mechanisms underlying self-relevant prioritization are still unclear. It has been proposed that self-relevance can affect perception, decision making, and memory stages of cognition. We sought to elucidate the potential mechanisms affected by self-relevance using a visual search paradigm. We asked whether self-relevance of a target enhances search response times (RTs), and if so, whether such enhancement involves improvements to search efficiency, which is often viewed as a proxy for perceptual salience of a target. During a brief training period, subjects learned that three unique shapes with different colors were associated with the labels SELF, FRIEND, and OTHER. These stimuli were then used as the targets in a visual search task, with target pre-cued from trial-to-trial using the trained labels. Distractors were color and shape combinations not associated with the potential targets. Search set sizes was randomly varied (4, 8, 16, or 32), allowing us to examine the RT x set size relationship as a function of target label. Confirming the effect of self-relevance on performance, SELF targets were found faster than the two non-self-relevant targets. Critically, both the intercept and the slope of the RT x set size function was reduced for SELF compared to the other labels. These results imply that self-relevance enhances the efficiency of visual search, an index often considered an indicator of perceptual salience. We propose that self-relevance enhances perceptual salience of self-relevant attributes, as reflected by search slope reduction. Effects on the intercept may reflect additional perceptual, memory, and/or decision-making processes influenced by self-relevance.

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63.4016 Modeling the Mechanisms of Reward Learning that Bias Visual Attention

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A body of recent research has shown that visual attention is biased toward rewarded stimuli. Because of the known role of the basal ganglia in reward learning, a potential mechanism for this bias is learning in striatal medium spiny neurons (MSNs), which receive projections from cortex carrying information about visual stimuli and from dopaminergic neurons carrying information about reward. Furthermore, their output can influence visual processing through the closed visual corticostriatal loop, that runs from the MSNs through globus pallidus/substantia nigra (GPi/SNr), thalamus, and back to visual cortex. We propose an implementation for this closed visual loop that includes a biologically plausible model for temporal cortical neurons and striatal MSNs, both simulated through the Adaptive Exponential Leaky Integrate and Fire (LIF) model with parameters constrained with data from the neurophysiological literature. Exponential LIF models were used for the GPi neurons as well as the thalamic neurons. Synapses between visual and striatal neurons are modified through a biologically-plausible reward-driven learning rule. Through association, the model initially adjusts these synapses based on the paired presentations of a particular color and a high reward or a lower reward. Adjustments were made until the reward prediction error was small. Using these acquired cortical-striatal weights while following the setup of a typical experiment in reward-based attentional bias, the model then selected a target shape from among five distractor shapes. One distractor had a previously-rewarded color. The model took significantly longer to make decisions when the distractor associated with a higher reward was present compared to when the distractor associated with lower reward was present. Thus, the model can explain reward-based attentional capture through neurobiologically-plausible learning mechanisms. Furthermore, the model is in line with results from the neurophysiological and neuroimaging literatures that implicate the visual corticostriatal loop in reward-based visual learning.

63.4017 Neural evidence that values of task-irrelevant visual and motor features are tracked in a reward-based decision-making task

Valerie Beck[1](vbeck@psych.udel.edu), Timothy Vickery[1]; [1]Department of Psychological and Brain Sciences, University of Delaware

Learned associations between sensorimotor features of available choices and the value of outcomes guide many real-world decisions. Reinforcement learning (RL) approaches attempt to account for such decisions, but are often applied in a manner that implicitly assumes only relevant, attended feature-value associations are tracked, updated via reward prediction errors (RPEs), and employed in decisions. We have previously found evidence that "task-irrelevant" location/motor-related value tracking signals appear in subcortical regions related to motor and reward, such as the ventral pallidum, as well as a cortical region of ventral temporal cortex. In this study, we examined whether task-irrelevant, purely visual features are tracked in a similar manner. Participants (N=20) were scanned using fMRI while they completed a "4-armed bandit" dynamic reward-learning task and were instructed to track shape-value while ignoring color and location. On each trial, four shapes (circle, square, pentagon, and octagon) were randomly positioned in four locations on the screen, and randomly bound to each of four different colors (red, yellow, green, and blue). Participants were correctly informed that value was associated with shape, with the value of each shape determined by a hidden probability of receiving a reward that varied stochastically. Behaviorally, we found weak evidence based upon RL modeling that, in addition to shape-value, participants also tracked color-value and location-value and allowed them to influence choice. Replicating earlier work, we found correlates of location-linked RPE signals in subcortical regions of the basal ganglia, as well as a cluster of ventral temporal cortex. Critically, we also saw color-linked RPE signals in subcortical regions of the basal ganglia. These results suggest that both motor and non-motor "irrelevant" attributes are latently tracked with respect to their association with reward. Such latent signals may serve to guide exploratory actions, or actions taken under high uncertainty.

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63.4018 Prismatic Adaptation Boosts Feedback-Based Learning

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Visuospatial cognition has an inherent spatial bias. Notably, the individual differences in the direction and magnitude of this bias are associated with the asymmetric pattern of binding of dopamine D2/3 receptors, as well as with dopamine system genes. Recent data also indicate that the hemispheric asymmetry of dopamine signaling is related to the propensity to learn from positive vs. negative feedback: High D2 receptor binding in the left hemisphere is associated with preference for rewarding events. Prismatic adaptation is a simple sensorimotor technique able to modulate visuospatial cognition according to the direction of the deviation. Left deviating prisms are hypothesized to induce a rightward bias in healthy subjects by inhibiting the posterior parietal cortex opposite to the prismatic deviation, via ipsilateral cerebellum, and releasing the contralateral hemisphere from interhemispheric inhibition. However, despite years of research, agreement on the exact mechanism of prismatic adaptation has not been reached. We hypothesize that left-deviating prism adaptation would decrease learning with negative feedback and increase learning with positive feedback. Healthy volunteers performed a two-choice feedback probabilistic classification task, which allows comparison of reward and punishment sensitivity, before and after adaptation to left prisms. On each trial, participants viewed one of four unrelated images, two belonging to a reward-learning condition and two to a punishment-learning condition, such that each category contained one rewarded and one punished stimulus. Correct trials yielded points in the reward condition, whereas incorrect trials decreased participants' score in the punishment condition. The rate of spontaneous blinking was recorded as an indirect measure of dopamine activity. Consistent with the hypothesis, preliminary results show an increase in learning rate only for positively reinforced items. These results suggest that prismatic adaptation acts asymmetrically on the dopamine system.

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ATTENTION: TRACKING, TIME AND SELECTION

Wednesday, May 24, 8:30 am - 12:30 pm
Poster Session, Pavilion

63.4019 Attention can be flexibly distributed between targets in multiple object tracking

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Multiple object tracking studies typically find a severe capacity limitation on the number of targets that can be accurately tracked. Our research investigated whether this resource is discrete or continuous in nature. The discrete account holds that each target receives a fixed resource amount that can be conceptualized as a pointer or index (Pylyshyn & Storm, 1988). In contrast, the continuous resource account posits a flexible distribution of resources between targets. A critical test for these accounts is the ability of observers to endogenously control the amount of resources allocated to different targets. We investigated this prediction by incentivizing observers to allocate more attention to one target vs. another. Our task required observers to localize targets that moved along circular tracks. We used the mixture model (Bays, Catalao, & Husain, 2009; Zhang & Luck, 2008) to derive estimates of tracking precision and number of objects tracked. Consistent with the continuous resource account, we found that a high priority target was tracked with greater precision ($M = 15.31$ degrees) than a low priority target ($M = 19.30$ degrees; $t(12) = -4.89$, $p < .001$). It appears that people have flexible control over resource allocation between targets and that increased attention to a target increases tracking precision.

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63.4020 'Serial-like' sampling of visual objects during sustained attention

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In a crowded visual scene, attention must be efficiently and flexibly distributed over time and space to accommodate various contexts. It is well established that selective attention enhances the corresponding neural responses, presumably implying that during sustained attention (e.g., focusing on one over others), attention would persistently dwell on the task-relevant item. Meanwhile, recent studies propose that attention, rather than being stationary, is essentially a dynamic process that organizes copious information temporally. However, how the brain dynamically coordinates attention among multiple visual objects during sustained attention remains largely unknown. To address the issue, here we employed electroencephalography and a temporal response function (TRF) approach to extract object-specific neuronal impulse responses in sustained attentional tasks. First, we demonstrate that attentional process, characterized by inhibitory alpha (~10 Hz) activities in TRFs, switches between the attended and unattended locations, suggesting rhythmic sequential sampling even during sustained attention. Furthermore, the attentional spatiotemporal pattern is modulated by task contexts such that the alpha-mediated switching becomes increasingly prominent as the task requires more uniform attentional distribution. Finally, this attentional spatiotemporal profile maintains in a multiple-object-tracking (MOT) paradigm, indicating a general temporal organization mechanism for object-based attention. Our results suggest that sustained attention, in addition to the classically posited attentional 'focus', contains a dynamic mechanism for monitoring all objects outside of the focus. Our findings also advocate that attention is intrinsically dynamic, acting as a series of concatenating attentional chunks that operate on one object at one time.

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63.4021 The cognitive benefits of NeuroTracker training across neurodevelopmental disorders: Who benefits from training attention with multiple object-tracking?

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A previous school-based study found that training with a Multiple Object-Tracking paradigm (NeuroTracker) improved performance on a clinically validated measure of attention, for students diagnosed with a neurodevelopmental disorder (Tullo, Guy, Faubert, & Bertone, 2016). Autism Spectrum Disorder (ASD), Attention Deficit Hyperactivity Disorder (ADHD), and Intellectual Disability exhibiting different profiles of attention; therefore, an examination of which clinical profile benefits most from visuo-attentive NeuroTracker training can provide additional information to tailor cognitive remediation programs from a needs-based perspective. We explored the effect of training attention with NeuroTracker for students diagnosed with ASD compared to those diagnosed with other neurodevelopmental disorders. One hundred and twenty-nine students were included in the study (Mage = 13.24). All participants had a primary diagnosis of either ASD ($n = 43$), or any other neurodevelopmental disorder ($n = 86$; i.e., ADHD, Intellectual Disorder). A pre-assessment measure of attention was obtained for all participants via the Conners Continuous Performance Task (CPT-3) and then all participants were equally and randomly into; the experimental NeuroTracker training group ($n = 43$, $nASD = 16$), active control group ($n = 43$, $nASD = 9$) playing a strategy-math game: 2048, or treatment as usual group ($n = 43$, $nASD = 25$). After 15 training sessions, participants were reassessed on the CPT-3. Training by diagnostic group revealed that NeuroTracker performance doubled from the first to the final training session for both the ASD and non-ASD groups. Furthermore, there was no significant difference between change in CPT-3 scores after training

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with NeuroTracker between the ASD and non-ASD groups. Our findings demonstrate that training with NeuroTracker can benefit all students with problematic levels of attention, regardless of primary diagnosis. These results suggest that the Neurotracker training program is accessible and effective for children and adolescents with a neurodevelopmental condition that is independent of diagnostic profile.

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63.4022 **Multiple object tracking in peripheral vision** Arijit Chakraborty[1](arijit.chakraborty@uwaterloo.ca), Kevin Hua[1], Laura Chan[1], Deborah Giaschi[2], Benjamin Thompson[1]; [1]School of Optometry and Vision Science, University of Waterloo, [2]Department of Ophthamology, University of British Columbia

Most attentive motion tracking studies have been restricted to central vision. Peripheral vision can support global and biological motion perception, although speed thresholds and noise tolerance are poorer than in central vision. We investigated peripheral attentive motion tracking using a multiple object tracking (MOT) task (n=15, 27±3 years of age). The potentially confounding effect of crowding was assessed by 1) manipulating the spacing between MOT task elements, and 2) conducting a numerosity judgement control experiment. Speed thresholds for a multiple object tracking (MOT) task involving 4 circular targets (1˚ diameter) and 4 identical distractors were measured using a 2-up 1-down staircase. Thresholds (based on partial report) were measured across 4 eccentricities (0˚, ±5˚, ±10˚, and ±15˚) with minimum element spacing set to 0.15˚, 0.6˚ and 1.5˚. The numerosity judgement task involved presentation of static frames from the MOT task within a temporal 2-alternate forced choice paradigm. Participants (n=12) judged which frame contained the most elements. MOT speed thresholds fell with eccentricity for every stimulus spacing. There was an approximately 5-fold reduction in threshold from central vision to 15˚ of eccentricity. There were no hemifield effects. Analyses of the speed thresholds revealed an interaction ($F = 12.25$, $p < 0.001$) between eccentricity and element spacing whereby an advantage of larger stimulus spacing in central vision was absent in the periphery. The opposite effect ($F = 49.05$, $p < 0.001$) was observed for the numerosity control task, whereby an advantage of larger stimulus spacing was more pronounced in the periphery than in central vision. This suggests that the effect of eccentricity on MOT speed thresholds was not solely due to peripheral crowding. Our results indicate that although attentive motion tracking is possible in the periphery, speed thresholds are dramatically reduced. This may limit the use of peripheral vision for attentive tracking in real-world situations.

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63.4023 **Brain Areas Specific for Feature-based and Symmetry-based Groupings in Multiple Object Tracking** Chundi Wang[1](wangchundi@mail.bnu.edu.cn), Luming Hu[1], Xuemin Zhang[1,2,3]; [1]Beijing Key Lab of Applied Experimental Psychology, School of Psychology, Beijing Normal University, Beijing, China, [2]State Key Laboratory of Cognitive Neuroscience and Learning and IDG/McGovern Institute for Brain Research, Beijing Normal University, Beijing, China, [3]Center for Collaboration and Innovation in Brain and Learning Sciences, Beijing Normal University, Beijing, China

Multiple object tracking (MOT) is widely used for studying sustained attention in dynamic environments. Previous research reported inter-target grouping based on feature similarity (e.g., targets sharing the same color or shape) can facilitate tracking. A recent study also found that symmetric relation among targets in MOT tasks can automatically improve tracking performance. And an additive grouping effect of symmetry and feature similarity was observed, but two feature-based groupings were not additive. This study used functional magnetic resonance imaging (fMRI) to identify brain areas involved in feature-based and symmetry-based groupings in MOT. The present study included five conditions of inter-target groupings based on different grouping cues or their combinations: no grouping, symmetry-based grouping, symmetry-color-based grouping, color-based grouping, and color-shape-based grouping. Comparing the symmetry-based grouping condition with the no grouping condition revealed significant differences in anterior cingulate, the middle temporal gyri, inferior temporal gyri, postcentral gyri, superior frontal gyri medial, right lingual gyrus, right calcarine, and cuneus. Comparing the color-based grouping with the no grouping revealed significant differences in temporoparietal junction (TPJ), inferior parietal sulcus, putamen, middle and superior frontal gyrus, and anterior cingulate. The results of our study showed that putamen and temporoparietal junction (pTPJ) were involved in feature-based groupings, and middle temporal gyri, inferior temporal gyri and the cuneus were associated with symmetry-based grouping. The putamen is activated in all feature-based groupings, which indicated that when targets and distractors process different feature, tracking is facilitated by keeping the targets feature and ignoring the distractors feature. Our findings indicate that in feature-based inter-target grouping conditions, attention is more easily oriented and maintained towards targets during tracking. And in symmetry-based grouping condition, attention is less divided, and symmetric dynamic scene made up of targets is less complex to process.

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63.4024 **Modeling motion extrapolation in multiple-object tracking** Andrew Lovett[1](andrew.lovett.ctr@nrl.navy.mil), Will Bridewell[1], Paul Bello[1]; [1]U.S. Naval Research Laboratory

Research on multiple-object tracking suggests that the visual system can track targets through occlusions by extrapolating future positions from past motion. Evidence for such extrapolation is clearer with a smaller number of targets. Specifically, Luu and Howe (2015) showed that participants were able to track two targets better with predictable motion trajectories than with unpredictable ones. In contrast, accuracy was unchanged across conditions when tracking four targets unless trial types were presented in blocks. To investigate extrapolation during tracking, we developed a computational model based on two ideas. First, a pre-attentive, parallel process tracks targets by enhancing their locations while inhibiting the surrounding area. Second, a post-attentive, serial process computes motion trajectories for a single target and predicts its future location. Attention is drawn to targets that are crowded by other objects. As the number of targets increases, so does the amount of crowding and the number of occlusion events. As a result, the ability to serially extrapolate each object's location through occlusions decreases. Following their procedure, we compared the model to Luu and Howe's experiment 1. In line with the human data, the model's accuracy was higher in the two-target condition when trajectories were predictable (81.1% vs. 68.3%, $p < .05$). Contrary to their findings, accuracy was also higher in the four-target condition with predictable trajectories (81.6% vs. 72.8%, $p < .05$). These results suggest that although the model struggles with four targets—to equate accuracy, videos with four targets must be run at half the speed—it still benefits from motion extrapolation. Luu and Howe's experiment 4, where unpredictable trials appeared in separate blocks, similarly showed extrapolation for both two and four targets. Perhaps people rely on extrapolation in easy (two targets) or reliably beneficial (blocked conditions) situations, whereas the model always performs the more effortful strategy.

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63.4025 **The effect of stereoscopic cues on multiple object tracking in a 3D virtual environment** Steven Oliveira[1](solivei2@fau.edu), Mohammed Islam[1], Elan Barenholtz[1], Regynald Augustin[1], Shannon Whitney[1]; [1]Psychology, Florida Atlantic University

Research on Multiple Object Tracking (MOT)—the ability to track several target objects with independent motions among a set of distracters— has typically involved 2-dimensional displays in which the stimuli move in a single depth plane. However, under natural conditions, objects move in three dimensions which may yield additional challenges or potential benefits to tracking. To date, only a small number of studies have been conducted using stereoscopic 3D depth in an MOT context and none, to our knowledge, have directly assessed the role of stereo in tracking performance. To investigate this, we used a fully immersive virtual-reality environment (HTC VIVE) in which participants were required to track 2 to 5 moving objects out of 8 total objects. The tracked objects were spheres that moved in an environment that was frictionless and gravity-less but with real world bouncing mechanics. We compared performance to a condition in which participants viewed the same stimuli without stereoscopic depth cues (the VR stimuli seen on a standard computer screen). Results showed that participants were more accurate in the VR condition than the 2D environment with 3D cues. These results demonstrate that people can successfully track multiple objects moving in three dimensions and that stereoscopic information facilitates this ability. The obtained results also suggest that stereoscopic displays provide a more ecologically valid context for MOT experiments, than traditional setups 2-dimensional displays.

63.4026 **Fate of the extra item in multiple identity tracking task** Lauri Oksama[1](loksama@utu.fi), Maria Kuvaldina[2], Jukka Hyönä[3]; [1]National Defense University, Finland, [2]St.Petersburg State University, Russia, [3]University of Turku, Finland

It has been shown that inattentional blindness, omission of the unexpected extra item once attention is engaged in some other task, is dependent on perceptual load (Cartwright-Finch & Lavie, 2007) and attention set (Most, 2011). Here, we were interested in the question on how the extra item is processed during a multiple identity tracking task, a real-life task, where sustained attention is engaged to distinct moving identities (e.g Oksama & Hyönä, 2008). We manipulated the familiarity of the attention set (whether the tracked identities were repeated or varied between the trials), task load (the number of targets and distractors from 2 to 4) and the presence of an extra item during the tracking task. Besides doing the tracking task, participants also counted the bounces of the targets by pressing the keyboard continuously during a trial. We measured the accuracy of target, distractor and extra item recognition, the accuracy of the bounce calculation and participants' eye-movements during the task. We found that the rate of the extra item omission increased when tracked identities were less familiar and when the target or distractor set-size increased. Furthermore, the bouncing accuracy decreased in the extra-item-present trials compared to extra-item-absent trials. Fixation duration, number of fixations and saccade velocity were sensitive to the extra item whereas pupil size' sensitivity was mediated by number of factors. In sum, the extra item appearance increases perceptual/cognitive load of the task. The processing of extra items during multiple identity tracking is discussed in the light of the present results.

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63.4027 **The cost of time in multi-object tracking tasks.** Austin Kuo[2,3](austinchkuo@gmail.com), Kathryn Bonnen[2,3], Alexander Huk[1,2,3], Lawrence Cormack[1,2,3]; [1]Psychology, College of Liberal Arts, The University of Texas at Austin, [2]Neuroscience, College of Natural Sciences, The University of Texas at Austin, [3]Center for Perceptual Systems, The University of Texas at Austin

In a typical multiple-object tracking experiment, observers are shown moving target objects amidst similar distractors and are asked to identify which of the objects were targets at the end of each trial; these studies provide a snapshot of attentional performance at some fixed point in time. In our study, we instead had observers (4 naïve, 2 authors) track the perceived centroid of a number of moving targets in real time amidst visually identical distractors over the course of long (20 s) trials. This resulted in a continuous assay of attention vs. time within individual trials. All of the objects were bright squares (11x11 arcmin) against a middle gray background, and the "targets" temporarily turned purple and then returned to white before each trial began. Each object did an independent random walk with the constraint that objects were not allowed to collide. We varied both the number of targets and distractors across conditions. Our results show that the absolute Euclidean error of centroid estimates (the straight-line distance between the perceived and actual centroids) increased linearly with time; in other words, the longer observers had to track, the further afield their estimates became. Moreover, the "cost of time" (the slope of the error-vs.-time data) itself depended linearly on both the number of targets and the number of distractors. Our results support the notion that attention in multiple-object tracking tasks is a fluid resource that can be distributed amongst various numbers of objects, but further suggest that this resource is depleted over time at a rate that depends on task difficulty.

63.4028 **The effect of different color combinations on multiple object tracking: an fMRI study** Luming Hu[1](hlmpsy@163.com), Chundi Wang[1], Xuemin Zhang[1,2,3]; [1]Beijing Key Lab of Applied Experimental Psychology, School of Psychology, Beijing Normal University, Beijing, China, [2]State Key Laboratory of Cognitive Neuroscience and Learning and IDG/McGovern Institute for Brain Research, Beijing Normal University, Beijing, China, [3]Center for Collaboration and Innovation in Brain and Learning Sciences, Beijing Normal University, Beijing, China

Previous studies showed that surface feature (e.g color, shape) served as an important role during multiple object tracking (MOT). Different feature combinations may result in different tracking performance. Hence, we decomposed three main predictive variables from the different color combinations of objects, which were color distinctiveness between the target set and distractor set (DTD), the color complexity of target set (CT), the color complexity of distractor set (CD). In the current study, we employed functional magnetic resonance imaging (fMRI) to investigate the neural mechanism of the effect of different feature combinations (i.e color) during MOT. 22 participants were recruited with within-subjects repeated measure design and then four conditions were conducted. The neuroimaging data analyzed by permutation-based non-parametric one-sample t-tests (family-wise error cluster level at $p < .05$) supported further behavioral results. There was no significant activity difference between Inter-target-1 and Inter-target-4. And compared to Inter-target-4, all unique condition showed increased activations in inferior frontal gyrus (p. Triangularis, IFG), intraparietal sulcus (IPS), superior parietal lobule (SPL), precuneus in left hemisphere, angular gyrus (AG), middle frontal gyrus (MFG), IFG (p. Opercularis), precuneus in right hemisphere. In the contrast of paired-four versus Inter-target-1 and paired-four versus Inter-target-4, both of them showed positive activations in bilateral MFG and negative activations in bilateral rectal gyrus, right putamen, left superior medial gyrus, and right linual gyrus. These findings provide neuroimaging evidences that the color complexity of target set (CT) has similar effect on tracking as tracking load, while the color complexity of distractor set (CD) does not. Color distinctiveness between target set and distractor set enhances tracking performance by to maintaining selectively attention towards targets during tracking, and putamen plays an important role for distinguishing targets from distractors during tracking.

63.4029 **Hemifield-specific attentional spotlights are dependent on a common global tracking template** Roger Strong[1](rstrong@fas.harvard.edu), George Alvarez[1]; [1]Department of Psychology, Harvard University

The left and right visual hemifields appear to have separate spotlights of attention, as two targets divided between hemifields can be tracked as well as one target within a single hemifield (Alvarez & Cavanagh, 2005). Unresolved, however, is how these separate spotlights are integrated with global feature-based attention, where focusing on a particular feature facilitates processing of that feature throughout the entire visual field (Sàenz, Buraĉasa, & Boynton, 2003). Here we examined tracking of multiple targets across the hemifields when those targets could have different motion features, either rotating around a central point, or translating freely. Although accuracy for tracking two targets with the same motion type (uniform tracking: both rotation or both translation; M=82.6%) was not significantly different than accuracy for tracking a single target (M=85.3%, p=.28), tracking performance decreased significantly when tracking two targets with different motion types (mixed tracking: one rotation + one translation; M=70.3%, p=.001). The cost for mixed tracking was greater for the rotation condition than the translation condition. We hypothesized that attention must alternate between separate global feature templates for translation and rotation, and that the asymmetry in the cost for mixed tracking reflects an asymmetry in the cost incurred when briefly interrupting tracking for the two tasks. In Experiment 2 we quantified each motion type's interruption cost by periodically removing all items from the display (for 0, 50, 100, or 200 ms) while observers tracked a single rotating or translating target. A greater interruption cost was found for rotation than for translation, which mirrored a greater accuracy reduction for rotation than for translation during mixed tracking. These findings suggest the hemifield-specific attentional spotlights are dependent on a global tracking template, which repeatedly switches its tuning when multiple types of motion must be attended.

63.4030 **Detecting more than one event at a time in multiple event tracking.** Chia-Chien Wu[1,2](cchienwu@gmail.com), Jeremy Wolfe[1,2]; [1]Visual Attention Lab, Brigham & Womens' Hospital, [2]Harvard Medical School

In many surveillance situations, observers have to monitor for an event (e.g. Did anyone pass a bag to someone else?). Our previous work shows that the capacity for event monitoring is more limited than for classic multiple object tracking. However, it is not clear if a capacity of K events means that people can detect K events simultaneously or only that they can successfully detect one event at a time while monitoring K out of N items. In the first experiment, observers tracked 4-8 moving, unique objects for up to 8 seconds. Two target objects experienced state changes (e.g. open bottle to closed bottle). In one block, changes were simultaneous. In the other, changes were sequential. In the second experiment, displays contained 4-8 identical disks, each "carrying" a black bag along with 4 disks carrying no bag. All items moved pseudo-randomly. In one block, two disks would drop their bags simultaneously. In the other, only one bag drop occurred. In both experiments, observers had to report the target event(s) within two seconds after the change(s) occurred by clicking on the target disk(s). Otherwise, the trial was considered a "miss". In Experiment 1, performance was similar in the simultaneous and sequential change conditions (mean accuracy 51.7% vs. 48.8%). There was no penalty for simultaneous presentation. In Experiment 2, the detection was essentially identical in single target condition and dual target condition (mean accuracy 59.6% vs. 59.7%) meaning that observers located two drops as readily as one. These data are more compatible with a model that includes an ability to detect two changes at once than with a model limited to only one detection at a time. Our results suggest that a capacity of K in multiple event tracking may represent the number of event people can detect simultaneously.

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63.4031 Sequential Sampling in Visual Attention

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Both space- and object-based attention facilitate the selection of relevant information within the visual environment. Utilizing the classic Egly task, Fiebelkorn, Saalmann & Kastner (2013) recently demonstrated a temporal relationship between both visual attention mechanisms, whereby periods of peak target detection at cued and uncued locations within an attended object share a common 8 Hz frequency with offset phases. We set out to investigate whether the observed sampling rate would be fixed across a range of task conditions, or if instead it is under strategic control. We first extended the observation of consistent sampling rates at within-object locations to a challenging target discrimination task relying on an endogenous spatial cue with 80% validity. On the remaining 20% of trials, the spatial cue was equally likely to appear in an invalid location on the same object, or an invalid location on a different (equidistant) object. Across all trial types, within-subject target discrimination accuracy was constrained to fall between 55-75%. A variable cue-to-target interval ranging from 300 – 1175 ms was used to allow for spectral analysis of the hit rate at each target location over time. Consistent with a large body of literature on space-based attention, response times were faster in the valid condition relative to the invalid conditions. However, an analysis of the hit rates did not produce space- or object-based attention effects of the magnitude previously reported. Nonetheless, the frequency analysis revealed a periodic reweighting of attention at both within-object locations at approximately 8 Hz. This suggests that the rhythmic sampling reported in the previous research may be robust against certain changes in task demands and performance. Ongoing research aims to test whether the periodicity of space- and object-based attention effects may be modulated by manipulating the behavioral relevance of each location.

63.4032 Fast and flexible: dynamic adaptation of temporal expectation

Chiron Oderkerk[1](chiron.oderkerk@gmail.com), Anders Petersen[1], Claus Bundesen[1], Signe Vangkilde[1]; [1]University of Copenhagen

Accurate temporal expectation about an event should reflect its hazard rate, i.e., the probability it will occur in the next possible moment, given that it hasn't yet. Indeed, the speed of perceptual processing of visual stimuli has been found to change as a function of the hazard rate of those stimuli when varied between blocks of trials in visual recognition paradigms (Vangkilde, Coull, & Bundesen, 2012). In this study we investigated the dynamic adaptation of temporal expectation over time. We used two alternating hazard rates over the course of a variable cue-stimulus foreperiod, and measured participant response times in a speeded visual discrimination task. During the foreperiod, a coloured fixation cross would alternate between two colours, each denoting either a high or a low constant probability that the target stimulus would appear in the next possible moment. Foreperiods were distributed using discrete time steps of 400 ms, each with a high or a low probability that the stimulus would appear on that time step. Consecutive time steps with the same hazard rate were grouped together into epochs such that the probability that the stimulus would appear during the next time step was dependent on whether that time step was located during a high or a low probability epoch. We found significantly faster responses to stimuli presented during high probability epochs than during low probability epochs. This indicates that participants were not only able to adjust their temporal expectation, but could do so fast and flexible enough to reflect the change in hazard rate.

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63.4033 Selective attention modulates the temporal window of integration

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Constructing useful representations of our visual environment requires the ability to selectively pay attention to particular locations at specific moments. Whilst there has been much investigation on the influence of selective attention on spatial discrimination, less is known about its influence on temporal discrimination. In particular, little is known about how attention influences two fundamental and opposing temporal processes: segregation – the parsing of the visual scene over time into separate features, and integration - the binding together of related elements. In three experiments, we tested whether selective attention to a location can influence both of these opposing processes. The first experiment used a variant of the two flash fusion paradigm in which participants were cued to a spatial location at which the target(s) were likely to appear, and subsequently had to indicate whether they had seen a single target or two rapidly presented sequential targets. The second and third experiments used a paradigm in which participants were spatially cued to facilitate detection of a target in two rapidly presented sequential displays. Crucially, there were two types of targets present in each trial: a target for the segregation version of the task, and one for integration. As such, visual stimulation was the same across trials, whereas the appropriate processing strategy depended on current goals. In all experiments, there was a strong cueing effect on accuracy, including a cueing effect on both segregation and integration. These results support the hypothesis that selective attention can influence both of these opposing processes, effectively shrinking or expanding the integration window in line with task goals. The finding has implications for arbitrating between accounts of the multiple modulatory mechanisms comprising selective attention.

63.4034 The Time Course of Attentional Disengagement from Faces, Objects, and Scenes

Alissa Stafford[1](astaffo6@jhu.edu), Jason Fischer[1]; [1]Johns Hopkins University

To move our attention fluidly through a scene, we must disengage attention from each object or location before shifting to the next. Disengagement is a fundamental component of attentional orienting, and atypical disengagement is frequently studied in clinical populations as a potential factor in the etiology of a number of disorders. However, much less work has been done to establish the basic characteristics of attentional disengagement in typical observers. In particular, it remains unclear how the type of stimulus we are attending to influences the time it takes to disengage from it. Here, we measured the time it takes to disengage attention from a stimulus (disengagement cost) as a function of stimulus category (neutral faces, everyday objects, and scenes) and stimulus duration (.5s to 4s, in increments of .5s). We hypothesized that disengagement from faces would be slowest due to their social content, but that this effect would be diminished at longer viewing durations after participants had performed some initial exploration of the images. In a series of eye tracking experiments, participants viewed centrally-presented faces, objects, and scenes and were instructed to quickly make a saccade to a peripheral target pattern that appeared after a variable delay from the onset of the central stimulus. Importantly, the central stimulus remained onscreen until after the saccade was completed, requiring participants to disengage attention before shifting to the peripheral stimulus. As predicted, we found that participants were slowest to initiate a saccade when disengaging attention from a face. Disengagement costs decreased at longer stimulus durations for all categories, but the elevated disengagement cost for faces was roughly constant across durations. These results point to two independent influences of stimulus category and stimulus duration on attentional disengagement.

63.4035 **Examining the distribution of multifocal attention in depth** Eugenie Roudaia[1](eugenie.roudaia@umontreal.ca), Delphine Gaudin[1], Delphine Bernardin[1,2], Jocelyn Faubert[1], Aarlenne Khan[1]; [1]School of Optometry, University of Montreal, [2]Essilor Canada Ltd.

Research on multiple object tracking has shown that we can track objects moving across the visual field with attention. Given that most studies used 2D stimuli, little is known about the characteristics of dynamic attention in depth. We examined how separation of objects across different depth planes affects tracking performance under free- and fixed-viewing conditions in two experiments. Stimuli were eight virtual tennis balls bouncing inside two virtual zones measuring 2.5 x 1.25 x 0.62 m (W x H x D) each, placed one above the other. There were two targets and two distracters in each zone. The task required tracking the target balls for 8 s. The speed of the balls was adjusted for each subject in a separate threshold procedure. Stimuli were displayed with binocular disparity on a large screen inside an immersive environment. In Experiment 1, 20 participants tracked targets located in two zones that were separated by 0, 0.62, 1.24, or 1.86m in depth. Participants' eye movements were not restricted. Results showed large variability across subjects and no effect of depth separation on performance. In Experiment 2, participants tracked targets while fixating in the center between the top and bottom zones located either at the same depth or separated by 1.86m. Performance was better (by ~6%) for the same-depth compared to the different depth condition in most subjects. Performance was also significantly better (by ~20%) in the lower compared to the upper visual field. The lower visual field advantage was also seen in two control conditions where participants tracked targets only in the top or in the bottom zone. These results are consistent with previous reports of better attentional resolution in the lower visual field. Distributing attention across depth planes appears to have a small detrimental effect on tracking performance in fixed-viewing mode.

Acknowledgement: Funded by an NSERC discovery grant and NSERC-Essilor Industrial Research Chair

63.4036 **Competition Between Foveal and Peripheral Attention Reveals Evidence in Favor of a Zoom-Lens Model of Attention** Ryan Ringer[1](rvringer@ksu.edu); [1]Kansas State University, Department of Psychological Sciences

Previously we used a gaze-contingent peripheral Gabor discrimination task to determine whether tunnel vision or general interference of attention results when (i) a foveal load is present and (ii) the peripheral stimuli have been scaled to be equally discriminable in single-task conditions (Ringer et al., 2016). We found that, while peripheral performance was near perfect and did not vary as a function of retinal eccentricity in single-task conditions, when simultaneously presented with a foveal L vs. T discrimination task, peripheral Gabor orientation sensitivity decreased with increasing eccentricity. The zoom-lens model of attention (Eriksen & Yeh, 1985; Eriksen & St. James, 1986) is the most intuitive explanation for these results, with a foveal attentional bias producing diminished peripheral sensitivity. However, our prior results do not account for potential competition between foveal and peripheral processing, and thus it is possible that multiple spotlights of attention (McMains & Somers, 2004) may explain processing peripheral and foveal targets in parallel. A zoom-lens account of attention predicts trade-offs between peripheral and foveal discrimination sensitivity, whereas a positive or neutral relationship between peripheral and foveal discrimination sensitivity would be predicted by a multifocal spotlight account. Multi-focal attention predicts processing difficulties as attention becomes increasingly divided, but not a foveal processing bias. Using our previous data, a hierarchical generalized linear mixed model was used to predict peripheral Gabor sensitivity as a function of retinal eccentricity, foveal response bias, and foveal task sensitivity. This showed peripheral Gabor sensitivity decreasing significantly with increased foveal load sensitivity. Though this effect did not interact with Gabor eccentricity, it is possible that our m-scaled peripheral stimuli mitigated this effect. Additionally, valid foveal stimuli (i.e., T present trials) produced faster, more accurate Gabor performance in the periphery, consistent with serial attentional switching. Thus we find converging evidence for the zoom-lens model of attention.

63.4037 **The Effects of Rhythm-Induced Attention on Perceptual Representation - Precision Analysis** Asaf Elbaz[1](asafelbaz@gmail.com), Yaffa Yeshurun[1]; [1]Psychology Department, University of Haifa

Temporal attention can be entrained exogenously to rhythms. Indeed, faster and more accurate responses were previously found when the target appeared in sync with a preceding rhythm in comparison to when it is out of sync. However, the nature of this rhythm-induced attentional effect is not well understood. To better understand how rhythm-induced attention may affect the quality of the perceptual representation, and specifically to test whether it improves the precision of the target's encoding, we employed a continuous measure of perceived orientation and the mixture-modeling analysis. A trial in our study started with a sequence of beeps separated by a fixed inter-beeps interval (400 ms; regular, rhythmic condition) or variable inter-beeps intervals (irregular condition). A target line followed the sequence. The 'critical' interval between the last beep and the target was chosen randomly from 4 possible Inter-Onset Intervals (IOI), of which one was 400 ms. The target was followed by a probe line, and the participants were asked to rotate it to assume the target's orientation. The measure of performance for a given trial was the difference in degrees between the orientation of the target and that reproduced by the observer. The results show a main effect for regularity: the standard deviation (SD) of report errors was significantly smaller when the observers were exposed to regular vs irregular rhythm. Importantly, there was also an interaction between regularity and IOI: when the target appeared 400 ms after the regular rhythm (but not after an irregular rhythm), a smaller SD of report error was found in comparison to other critical intervals (100, 200 and 600 ms). These results suggest that rhythm-induced attention improves the precision of perceptual representation.

Acknowledgement: Israel Science Foundation

ATTENTION: SPACE AND OBJECTS

Wednesday, May 24, 8:30 am - 12:30 pm
Poster Session, Pavilion

63.4038 **Is the attentional spotlight asymmetrical?** Nicole Thomas[1](nicole.thomas@flinders.edu.au), Michael Nicholls[1]; [1]School of Psychology, Flinders University

Cognitive load influences distractibility; distractors are more likely to be processed and slow reaction times during low cognitive load. In contrast, attentional resources are more limited during high cognitive load, limiting our ability to process peripheral stimuli. As a result, reaction times are quicker in the presence of distractors during high cognitive load. We manipulated distractor location to determine whether location differentially influenced the degree of distractibility. Participants (N=36) completed the irrelevant-distractor paradigm. On 80% of trials participants completed a visual search task, where they had to identify whether the target was an 'X' or an 'N'. In the low load condition, non-target stimuli consisted of lower case 'o' letters, whereas in the high load condition, heterogeneous angular letters, with the same dimensions as the target letter were used. In the remaining 20% of trials, a cartoon character appeared in the periphery (above, below, left or right of the visual search array). Reaction times (ms) were recorded on each trial. There was a strong effect of cognitive load, $F(1,29) = 124.992$, $p < .001$, $\eta 2 = .812$, as reaction times were faster during low load than high load. Importantly, the interaction of cognitive load and distractor location was significant, $F(1,29) = 39.489$, $p < .001$, $\eta 2 = .577$. During low load, reaction times increased equally for all distractor locations. In contrast, left distractors speeded reaction times significantly more than did right distractors during high load. We suggest that the attentional spotlight was sufficiently large to encapsulate both the distractor and the visual array during low cognitive load, leading to increased distraction, whereas the attentional spotlight split across the two visual stimuli during high load. Further, executive control is better in the left visual field, which prevents distraction and provides a greater performance benefit.

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63.4039 **The size of the attentional window when measured by the pupillary response to light** Shira Tkacz-Domb[1](shirtzi@yahoo.com), Yaffa Yeshurun[1]; [1]University of Haifa

Wednesday AM

This study explores the size of the attentional window, when attention is narrowly focused, with a measurement that is independent of performance - pupillary response to light. Previous studies demonstrated that when spatial covert attention is deployed to a bright area the pupil contracts relative to when attention is deployed to a dark area, even though display luminance levels are identical. We used these attentional modulations of the pupillary response to light to assess the spread of attention. Specifically, we examined how far light/dark task-irrelevant disks can be from the attended target and still lead to changes in pupil size. We presented a rotating T inside two squares, at an eccentricity of 6.75° to the right and left of fixation. Four task-irrelevant disks surrounded each square with varying inter-stimuli distances (1°, 4°, 7° and 11°). The luminance of the disks was bright on one side of the fixation and dark on the other. A central cue instructed observers to attend the right or left T and to count the number of times it assumed an upright orientation. With the three shorter distances, pupil size was smaller when the target was surrounded by bright than dark disks. Critically, this attentional effect on the pupillary response to light was eliminated at the largest distance. The results suggest that disks that were presented up to a distance of 7º fell within the attentional window. Moreover, the magnitude of the attentional modulation of the pupillary response to light decreased as the inter-stimuli distance increased suggesting that attention is not uniformly spread across the attentional window.

63.4040 **Attentional Selection Determines Saccade Endpoint** Luca Wollenberg[1,2](luca.wollenberg@gmx.de), Heiner Deubel[2], Martin Szinte[2]; [1]Graduate School of Systemic Neurosciences, Ludwig-Maximilians-Universität München, Munich, Germany., [2]Allgemeine und Experimentelle Psychologie, Ludwig-Maximilians-Universität München, Munich, Germany.

The premotor theory of attention postulates that spatial attention arises from the activation of saccade areas and that the deployment of attention is the consequence of motor programming. Indeed, oculomotor and attentional processes share neural circuitries (e.g. frontal eye fields and superior colliculi). Nevertheless, within the same areas, these processes can be dissociated in a covert attention task, eliciting activation of visual neurons without concurrent activation of motor neurons. This dissociation contradicts the premotor theory of attention and suggests that motor preparation and visual attention can be separated at the neuronal level. Can we find evidence of such dissociation at the behavioral level? Here, we instructed participants to make a saccade towards one of two competing saccade cues and measured attention using oriented targets presented either at the saccade cues, in between them or at several other equidistant locations. When saccades ended at one of the saccade cues, we found an expected pre-saccadic shift of attention, with improved visual sensitivity at the location that became the endpoint of a saccade over the other. As the two saccade cues were presented in close proximity we could dissociate the final saccade endpoint from the intended saccade goal. Indeed, this spatial arrangement led to a substantial proportion of averaging saccades landing in between the two saccade cues. Interestingly, when saccades landed in between the two cues, attention was equally distributed across them and not deployed at the position in between. This shows that attention is not strictly coupled to the motor program of a saccade, ruling out the premotor theory of attention at the behavioral level. Moreover, our results suggest that saccade vectors are determined by the state of attentional selection before the eyes start to move and that averaging saccades arise from an unresolved attentional selection.

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63.4041 **The Effect of Distance on Voluntary Shifts of Attention between Visual Objects** Michael Jenkins[1](mjenki02@mail.bbk.ac.uk), Anna Grubert[2], Martin Eimer[1]; [1]Department of Psychological Sciences, Birkbeck, University of London, [2]Department of Psychology, Durham University

In many visual search tasks, attention shifts between objects can be guided by the visual properties of these objects, but there are conditions where such shifts are elicited in a fully endogenous (voluntary) fashion. Using the N2pc component of the event-related potential (ERP) as a marker of attentional object selection, we have previously shown that such voluntary movements of attention can be triggered within less than 200 ms. Here, we investigated whether the time required by voluntary attention shifts between two objects increases as a function of the spatial distance between them. Search displays contained seven grey letters or digits and an additional coloured circle (benchmark object) that were arranged in a circular fashion around central fixation. Participants' task was to report the identity (letter or digit) of one particular target object that was defined by its location relative to the benchmark. A cue presented prior to each search display signalled that the target would be one, two, or three positions from the benchmark (clockwise or anticlockwise, varied across blocks). N2pc components to benchmark objects preceded N2pcs to targets by about 100 ms, demonstrating that as intended, attention was first allocated to the benchmark before it was voluntarily re-allocated to the target object. Reaction times and errors increased linearly as a function of benchmark-target distance, suggesting longer shift times for larger distances. Surprisingly, the N2pc to target objects emerged at the same time for all distances. In a second experiment, we showed that N2pc components reflect the time point when the attentional focus moves into the contralateral hemifield rather than when it reaches the target. The N2pc associated with attention crossing the vertical meridian emerged later when the benchmark was further from the midline, suggesting that voluntary attention takes longer to shift to more distant locations.

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63.4042 **Saccadic evidence for spatial hyperfocusing in people with schizophrenia** Carly Leonard[1](carly.leonard@ucdenver.edu), Benjamin Robinson[2], Britta Hahn[2], Steve Luck[3], James Gold[2]; [1]Department of Psychology, University of Colorado Denver, [2]Maryland Psychiatric Research Center, University of Maryland School of Medicine, [3]Center for Mind and Brain, University of California, Davis

During daily functioning, a person makes thousands of goal-driven saccades to align the receptor-rich fovea with task-relevant information from the visual field. People with schizophrenia (PSZ) are known to be impaired at daily functioning, and recent work from our group suggests a tendency to hyperfocus on a subset of information might contribute to such dysfunction. Consistent with the related hypothesis that schizophrenia is associated with spatial hyperfocusing, Luck et al. (2014) found that a parafoveal distractor presented at a task-irrelevant location (either above or below central fixation) produced greater saccadic interference to a lateralized target in PSZ than in healthy controls (HCS). However, this previous experiment used only a single distractor distance, making it impossible to differentiate between a generalized impairment due to distractor presence and an increase in spatial attention to locations near the point of fixation. In the current experiment, participants made speeded saccades to a peripheral target that was equally likely to be presented to the left or right of fixation at 5° eccentricity. On 80% of trials, the peripheral lateralized target was presented simultaneously with a task-irrelevant distractor, which was positioned above or below fixation at a distance of either 1.5° or 5°. Participants also completed a short block without distractors to assess baseline performance. Analysis of first fixation location showed increased interference in PSZ compared to HCS for the distractors close to fixation but not those farther away. Between-group differences in other behavioral and saccadic metrics will also be discussed. Overall, these results support a spatial hyperfocusing account rather than a generalized attentional impairment in PSZ.

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63.4043 **Flanker Effects Reflect (Early) Suppression Delays Rather Than (Late) Response Competition** Ricardo Max[1](ricardo.max@nyu.edu), Yehoshua Tsal[2]; [1]New York University, [2]Tel Aviv University

When a target (two alternative identities) is flanked by incongruent distractors (bearing the alternative target identity), responses are typically slower compared to neutral flankers (Eriksen & Eriksen, 1974). A golden standard for investigating attentional selection, the flanker effect (slower responses for incongruent displays) has been traditionally interpreted as a late time-consuming competition between post-perceptual representations of both target identities that simultaneously activate both motor responses. This response compatibility effect has been exclusively attributed to the response system rather than to the perceptual or cognitive processing of the stimuli (Eriksen, 1995). If so, processing proceeds similarly for both display types during early stages, but is prolonged within incongruent displays during late post-perceptual stages. We tested this prediction in a series of experiments employing the mutations paradigm (Max & Tsal, 2015), by comparing between the processing timecourses of incongruent and neutral displays. Methods: (a) While the target remained constant until response, distractors mutated once, at a random time within 100 ms following stimulus onset. Three types of mutation trials — incongruent distractors mutated to neutral; vice versa; or neutral to neutral (control) — were intermixed with baseline trials (incongruent and neutral displays without mutations). Comparisons between different trial types within each mutation time, revealed the time-window during which (disruptive) distractor information was accumulated. (b) Incongruent and neutral displays masked at random times revealed until when critical target information was accumulated (after which masking became inconsequential). Results: Incongruent distractors were suppressed 42 ms later than neutral distractors (at 67 and 25 ms, respectively). Following distractor suppression, exclusive target processing persisted for additional 24 and 33 ms (respectively), followed by additional 355 and 356 ms until response (at 446 and 414 ms, respectively). Conclusions: The 32-ms-slower responses for incongruent displays (flanker effect) reflected the 42-ms delay necessary to suppress incongruent distractors (initial pre-selection stage), rather than a late post-perceptual response competition.

63.4044 **Distinguishing among theories of selective attention using the flanker paradigm** John Palmer[1](jpalmer@uw.edu), Cathleen Moore[2]; [1]Department of Psychlogy, University of Washington, [2]Department of Psychological and Brain Sciences, University of Iowa

The flanker paradigm has been used to study selective attention across many domains, and alternative theories have been proposed to account for the flanker effects observed across those different domains (e.g., selective perception, response competition, selective decision, perceptual crowding). To facilitate testing alternative theories, we describe a theoretical framework that is defined by multiple properties. Here we focus on two: Does a given flanker effect derive from processes within immediate perception, later processes or both? Does a given flanker effect arise from selection error, non-selective interactive processing or both? We investigated these properties within a single domain: spatial selection with a simple feature judgment. A target and flanker were presented in the periphery, distinguished by only a spatial cue. Observers discriminated the color of the target and ignored the color of the flanker. Accuracy was measured as a function of whether the target and flanker were response congruent or incongruent, and as a function of their separation. Results revealed a large congruency effect that depended on separation. To test whether this flanker effect derives from processes within immediate perception or later processes, we compared simultaneous and sequential displays of the target and flanker. There was little or no advantage for the sequential display, consistent with none of the effect deriving from immediate perception, but occurring within later processes. To test whether this flanker effect derives from errors in selection or non-selective interactive processing, we manipulated the quality of cue. The observed effects were accounted for by independent processing of the target and flanker, combined with selection errors. No need for interactive processing. For this flanker effect, we find evidence of selection errors (not non-selective interactive processing) in later processing (not immediate perception). We look forward to applying this analysis to other applications of the flanker paradigm.

63.4045 **Explicit goal-driven attention, unlike implicitly learned attention, slips to secondary tasks** Douglas Addleman[1](addle005@umn.edu), Jinyi Tao[1], Roger Remington[1], Yuhong Jiang[1]; [1]Department of Psychology, University of Minnesota - Twin Cities

Spatial selection allows for preferential processing of certain visual information. Yet, the demands for spatial selection often differ between concurrent tasks. Here, we investigated how spatial selection in a visual search task affected processing of background scenes. We examined two types of spatial cues: explicit goal-driven cues and implicitly learned probability cues. In search, participants searched for a T among Hs; underneath the search array were four scenes, one per quadrant. Memory for the scenes was periodically tested. In two experiments (total N=48), endogenous cues indicated the quadrant most likely to contain the target T, engaging goal-driven attention. In two other experiments (total N=48), location probability learning was used to induce spatial attention: the target occurred more often in one visual quadrant than others. Both manipulations successfully induced an attentional bias toward the cued quadrant in the search task. To examine whether this bias spread to the secondary scene task, we compared memory for scenes placed in the quadrant cued for visual search versus scenes in the other quadrants. When spatial attention was endogenously cued, participants remembered scenes in the cued search quadrant significantly better than scenes in other quadrants. When using location probability cuing, participants could be aware or unaware of the target location probability. We separated participants into aware and unaware groups based on self-report. When participants were aware of the search target's location probability (N=22), the memory data were comparable with endogenous cuing data. In contrast, unaware participants (N=26) did not show transfer of the search bias to the memory task. These data suggest that goal-driven attention and incidentally learned attention engage different mechanisms. Goal-driven, but not implicit, attention transfers between concurrent tasks.

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63.4046 **Spatial recall performance: Differential landmark bias in schizophrenia** Sonia Bansal[1](ainos1785@gmail.com), Benjamin Robinson[1], Carly Leonard[2], Kyle Frankovich[3], James Gold[1], Steven Luck[3]; [1]University of Maryland School of Medicine, Maryland Psychiatric Research Center, [2]Department of Psychology, University of Colorado, Denver, [3]Center for Mind & Brain and Department of Psychology, University of California, Davis

It is known that people divide spatial regions into categories to enhance perception and interaction with the environment. Boundaries or landmarks are known to affect spatial memory and target localization due to the development of biases related to these 'categories'. Spatial recall tasks widely used to assess developmental changes in spatial memory in adult and children have shown biases in localization towards or away from a visible boundary. Although spatial working memory impairments are is among the hallmark neurocognitive deficits observed in schizophrenia, the exact spatial recall processes and landmark effects that contribute to spatial perception in schizophrenia remain unknown. Here we studied the effect of a visual landmark on spatial recall performance in people with schizophrenia and healthy controls to investigate bias patterns within each group. The task began with a fixation period, after which a target was briefly presented at a randomized horizontal distance either to the left or right of a centrally placed vertical line segment that served as a visual landmark. The target was then extinguished and after a delay period of 2s, subjects were instructed to click on the screen to indicate its remembered location. Target localization errors (derived as angular distance between target location and mouse click position) were analyzed and compared between groups across distances from the landmark. We show that controls were biased towards the visual landmark, particularly for targets located further away, whereas for those with schizophrenia, responses were biased away from the visual landmark.. The pattern of biases could reflect atypical spatial recall mechanisms in schizophrenia, whereby representations of the category information (In this case, left or right of landmark) and precise target location (proximity to the landmark) are differentially weighted compared to controls.

Acknowledgement: NIMH R01 MH065034

63.4047 **Object-based attentional selection emerges early in visual cortex for object percepts of varying strength** Shahd Al-Janabi[1](aljanabs@uwm.edu), Nofar Strommer-Davidovich[2], Shai Gabay[2], Adam Greenberg[1]; [1]Department of Psychology, University of Wisconsin-Milwaukee, [2]Institute of Information Processing and Decision Making, University of Haifa

Object-based attention (OBA) can - in addition to acting upon explicit object representations - act upon occluded objects and those defined by subjective contours. Thus, perceptual completion may precede the allocation of OBA. It remains unknown, however, whether or not such degraded object representations are selected at the same cortical level as explicit object representations. Such an investigation may indicate where in the visual cortical hierarchy perceptual object formation occurs. This study sought to ascertain the level within V1-V3 at which object-based selection is first observed for explicit versus degraded (occluded, illusory) objects. During fMRI acquisition, participants identified a target preceded by a predictive central arrow cue in the double-rectangle cueing paradigm. Behaviorally, participants identified the target faster when it appeared at the invalid-same versus invalid-different object location. This same-object advantage emerged regardless of object type, but, commensurate with recent data, was present only when objects were oriented horizontally. We independently localized retinotopically-specific regions of cortex corresponding to all possible target locations to examine neural fluctuations in each region of the visual cortical hierarchy. Consistent with our behavioral data, activation in V1 following cue onset increased within representations of the invalid-same versus invalid-different object location, which indicates prioritization of the same object location. This effect in V1 was restricted to horizontal objects. No such cue-evoked OBA effects were present in V2/V3. Additionally, activation in V1 following target onset increased when targets appeared in the invalid-different versus invalid-same object location. This effect, which may indicate a mismatch between where participants expected the target to appear, and the location in which it actually appeared, was evident only in representations of the invalid-same object location. No such target-evoked OBA effects were present in V2/V3. Thus, object-based selection occurs early in the visual cortical hierarchy, and does not depend on explicit object representations.

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63.4048 **Target location, rather than object location, drives the object-based attention shift direction anisotropy** Adam Barnas[1](a-jbarnas@uwm.edu), Adam Greenberg[1]; [1]Department of Psychology, University of Wisconsin-Milwaukee

Object-based attention (OBA) leads to preferential processing of visual information contained in/on an attended versus unattended object. We recently demonstrated that attention shifts across the visual field meridians resulted in faster reallocation of OBA horizontally than vertically (Shift Direction Anisotropy, SDA; Barnas & Greenberg, AP&P, 2016), suggesting a modulatory role of the meridians on OBA reorienting. Here, we aimed to determine whether the observed SDA caused by the visual field meridians depends upon the locations of targets, objects, or both. In three experiments, we utilized an 'L'-shaped object comprised of a horizontal rectangle fused to a vertical rectangle. Following a partially valid peripheral cue, participants detected the presence of a target at a cued location (valid condition) or at one of two noncued locations equidistant from the cue in either the horizontal (invalid-horizontal condition) or vertical (invalid-vertical condition) object component. For each experiment, we manipulated object and target location across the meridians (relative to the cued location) such that: (a) both object ends and targets either crossed the meridians or did not cross the meridians (Experiment 1), (b) object ends always crossed the meridians, but targets either crossed or did not cross the meridians (Experiment 2), and (c) targets never crossed the meridians, but object ends either crossed or did not cross the meridians (Experiment 3). Across all three experiments, the SDA emerged only when target location necessitated shifts of object-based attention that crossed the meridians. When target location did not necessitate shifts of attention that crossed the meridians, we observed no SDA, regardless of object location. These results demonstrate that the SDA is driven by target location, rather than object location, relative to visual field meridians, hence suggesting that OBA processes serve to prioritize specific target locations and not simply all locations within a cued object.

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63.4049 **Measuring the speed of attentional selection for two features concurrently from a single object reveals a foveal speed advantage for color** Chloe Callahan-Flintoft[1](ccallahanflintoft@gmail.com), Brad Wyble[1]; [1]Pennsylvania State University

Introduction and Methods The aim of this research was to measure the speed of attentional sampling of multiple dynamic features of the same object. To do this we presented stimuli that were smoothly rotating T-shapes that shifted through a cyclical color vector at 27 millisecond intervals. A circular cue indicated a point in time. Participants reconstructed the color and orientation of the shape at that time using mouse movements. Results Experiment 1 had participants monitor three changing T-shapes (one at the fovea and one on either side, five degrees apart with a 33% size increase to account for eccentricity), each equally likely to be cued. The results confirmed the pattern seen in pilot data where participants reported color information 77ms earlier for the shape in the fovea than the shape in the periphery while orientation report was similar across the fovea and peripheral locations. Experiment 2 replicated this result when all three shapes were of equal size. Again, a significant difference of 126ms was found in the mean latency shift of color reports. This time, a significant difference was also found in orientation report between foveal and peripheral presentation but the difference was still much smaller than for color. Therefore it is not the case that attention is overall slower to select information in the periphery but rather color appears to be accessed more rapidly in the fovea. Surprisingly, the standard deviation of the response distributions was not affect by eccentricity as one might have expected due to the distribution of photoreceptors in the fovea versus the periphery. These results thus suggest that attention accesses different features of the same object at different times, and there is a foveal latency advantage for color despite similar color precision.

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63.4050 **Does the Size of the Attentional Spotlight Constrain Global or Local Identification? Does Perceptual Load modify the Attentional Effect?** Thomas Sanocki[1](sanocki@usf.edu), Steven Schultz[1]; [1]Psychology, University of South Florida

How strongly does the attentional spotlight constrain identification? Does the effect vary with perceptual load? Strong hypotheses are that the spotlight enables identification within it while disabling identification outside of it, and that the effect increases with higher perceptual load as per perceptual load theory. The main spotlight effect measured here was that a large window would facilitate perceiving large or global letters (in hierarchical Navon stimuli) whereas a small window would facilitate small or local letters. However, we have found that large differences in spotlight-size have only modest influences on global or local identification. In the experiments, we use a new method for manipulating the attentional spotlight. On each trial, observers first track a rectangular frame that either broadened to become a big window or narrowed to become a small window. Then two hierarchical letters appeared for a brief duration, and observers reported the global and local identities. As in earlier experiments, large and small spotlights effected large and small letters about equally; there was only a very modest relation between spotlight size and identification at the two levels. However, the spotlight manipulation was valid because it caused large effects of left versus right side on the screen. The present experiments show that a manipulation that should increase attention effects — a manipulation of perceptual load — does little to increase the spotlight effect. We degraded the Navon letters, resulting in a large reduction in perceptibility (a sizable increase in perceptual load). Nevertheless, the spotlight effects remained very modest in size, indicating that there is little relation between spotlight size and identification of global or local letters.

63.4051 **The Effect of Object Size in Object-Based Attentional Selection** Joseph Nah[1](nah@gwu.edu), Marco Neppi-Modona[2], Lars Strother[3], Marlene Behrmann[4], Sarah Shomstein[1]; [1]The George Washington University, [2]University of Torino, [3]University of Nevada, Reno, [4]Carnegie Mellon University

While decades of research has provided evidence that within-object attentional shifts are faster than between-object shifts, most evidence is drawn from studies employing two objects that are identical in size. Thus, it remains unclear whether the size of an object influences attentional shifts within- and between-objects. Here, in a set of four experiments (3 behavioral and 1 eye-tracking), we manipulated the width of an object in a modified version of the classic two-rectangle paradigm by Egly et al. (1994). Participants were presented with one of three possible displays: (1) two identical parallel rectangles of two mixed widths (thin, thick), (2) two identical trapezoids (having both a thin and a thick end) that were inverted in orientation, or (3) two perceptually different yet physically identical parallelograms achieved by utilizing a variant of the famous Shepard's Table illusion. One end of an object was cued and participants performed a T/L discrimination or a target detection task, depending on the experiment. Combined results show that, in addition to the standard object-based effects, shifting attention within or between 'thick' objects or toward the 'thick' end of objects, resulted in significantly faster response times (RT) than the corresponding shifts of attention involving 'thin' objects or 'thin' object parts. The results were replicated with target detection tasks, providing evidence against a possible crowding explanation (targets in thin objects are detected more slowly because object edges are crowding the target). Additionally, object-based effects were replicated using eye-tracking measures (i.e., total number of saccades, saccade duration, saccade amplitude, peak velocity). Importantly, size effects were not observed in eye-tracking measures, providing further evidence against possible crowding effects. Taken together, these results suggest that deployment of object-based attention is modulated by properties of the object, such as its width; and that size affects attentional rather than motor processing

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63.4052 **Visual ensemble perception is not invariant across object types**

Yoshiyuki Ueda[1](ueda.yoshiyuki.3e@kyoto-u.ac.jp); [1]Kokoro Research Center, Kyoto University

We can summarize visually presented multiple objects at a glance and utilize it for further cognition (e.g., Ariely, 2001; Alvarez, 2011). This is called ensemble perception. In this study, to investigate invariance of ensemble perception, I asked participants to judge which of two categories in the majority of the group using four types of objects. If participants could perceive precious ensemble (e.g., mean or number) from multiple objects, the psychometric functions should be a sigmoid-shape regardless of object types. This is because mean of objects should be nearer to the template of one category than that of the other category when more than half of objects belong to this category, and participants can do the majority judgment correctly. Twelve objects belonged to either of two categories. The categories were decided based on color (red vs. green), shape (circle vs. square), size (larger vs. smaller than the exemplar), and facial expression (happy or angry vs. neutral) in each experiment. The identical objects were presented within each category in the experiments concerning to color and shape, whereas various objects were presented in those concerning to size and facial expressions. For color, shape, and size, participants could do the majority judgment accurately. Although the size judgment was less accurate than the color and shape judgments, the psychometric function of the size judgment showed a sigmoid-shape as the same as those of the color and shape judgments. However, the facial expression judgment was poor, and the psychometric function was linear. An additional experiment showed that participants did the majority judgment based on a part of faces rather than whole of them. These results suggest that ensemble perception is not invariant across object types and there would be the capacity limit for complicated objects.

63.4053 **Real-World Object Size Affects Attentional Allocation**

Andrew Collegio[1](ajcollegio@email.gwu.edu), Joseph Nah[1], Paul Scotti[1], Sarah Shomstein[1]; [1]Psychology Department, The George Washington University

Natural scenes consist of objects of varying sizes and shapes. Recent evidence shows that real-world object size influences topography of object representations in occipitotemporal cortex (Konkle & Oliva, 2012). The degree to which real-world object size influences attentional allocation remains unexplored. Here, we ask whether real-world object size influences attentional allocation. A spatial cueing paradigm was used, with cues highlighting one end of a single line-drawing of a real-world object, presented in the center of the screen. Participants performed a T/L discrimination task on targets that appeared either at the cued (valid) or uncued (invalid) location within the object. While objects subtended the same physical size, they varied in real-world size (e.g., domino, billiards table). Prior to experiments, objects were classified into two groups (small and large) according to a pre-determined metric. Across four experiments, the validity of the spatial cue (50% vs. 75% valid) and the temporal profile of attention (250ms vs. 500ms SOA) were manipulated. Upon completion of the experiment, participants rated the real-world size of each object in a post-experiment survey. In addition to validity effects, we observed direct evidence of real-world object size modulating attentional selection. In all experiments, targets were identified faster in small objects as compared to large objects. Importantly, no interaction between size and validity was observed, providing evidence for additivity of object size and validity. The direct relationship between inferred object size and target identification was validated by a strong correlation between individual's ratings of real-world object size and reaction times for individual objects (longer target identification RTs for larger objects). These findings offer a novel suggestion that knowledge of real-world size modulates attentional shifts, with overall more sluggish processing of spatial locations within larger objects and more efficient processing in smaller objects (i.e., scaling of attention).

Acknowledgement: NSF BCS-1534823 to S. Shomstein

Object Recognition: Neural mechanisms

Wednesday, May 24, 8:30 am - 12:30 pm
Poster Session, Pavilion

63.4054 **Electrophysiological correlates of animate/inanimate and graspable/tool object representations**

Gennadiy Gurariy[1](genaxl@yahoo.com), Gideon Caplovitz[1]; [1]University of Nevada, Reno

Vision has historically been subdivided into two major systems. The vision-for-perception system is thought to be responsible for generating visual representations in service of recognition and identification. Conversely, the vision-for-action system is thought to transform visual information towards the goal of guiding motor behavior. Both systems have been linked to distinct anatomical pathways - the ventral pathway, originating in early visual cortex and terminating in the temporal lobe, is thought to mediate vision-for-perception, while the dorsal pathway, originating in early visual cortex and terminating in the parietal lobe, is thought to mediate vision-for-action. While serving as a fertile and influential theoretical framework, growing body evidence suggests these processing streams may not be as independent as once thought. Our current investigation is predicated on the observation that many visuomotor behaviors (mediated through the dorsal pathway), such as the manipulation of man-made tools, are contingent on the successful identification of the object (mediated through the ventral pathway). Here we investigate the nature of these interactions using High-Density Electroencephalography (HD-EEG). We hypothesize that prior to being represented in the dorsal stream, tools should be differentiable from other categories of objects in the ventral stream. To test this hypothesis we conducted two HD-EEG experiments in which participants viewed images of animate objects (birds & insects) and inanimate objects (tools & graspable objects). Experiment one utilized the frequency-tagging approach and the Fast Fourier Transform to examine frequency domain amplitude differences between the object categories. Analyses reveal significant differences between the superordinate categories of animacy as well as differences between the subordinate categories. Experiment two utilized the event related potential approach. Analyses suggest a difference between animate and inanimate categories across central electrodes as well as a deviation of the tool category from the other object classes at frontal and posterior regions.

63.4055 **Characterizing the spatio-temporal dynamics of behavior-related neural activity during human visual object perception**

Radoslaw Cichy[1](rmcichy@gmail.com), Nikolaus Kriegeskorte[2], Jasper van den Bosch[2], Kamila Jozwik[1], Ian Charest[3]; [1]Department of Education and Psychology, Free University Berlin, Berlin, Germany, [2]MRC CBU, University of Cambridge, Cambridge, UK, [3]School of Psychology, University of Birmingham, Birmingham, UK

The ultimate goal of visual neuroscience is to understand the relation between visual input, neural processing, and human behavior. Analysis methods such as multivariate pattern analysis and comparison to deep neural network models of vision have recently improved our understanding of the relation between visual input and neural activity. In contrast, the use of such tools to understand the relation between neural activity and behavior has not received equal attention. Here, we investigated the relation between neural activity and behavior. As a measure of behavior, we acquired behavioral similarity judgments (N=20) for a set of 118 real world objects presented on natural backgrounds. We used representational similarity (RSA) analysis to relate behavior-derived representational dissimilarity matrices (RDMs) to fMRI and MEG (N=15) for the same stimulus set. Comparing behavior with fMRI spatial patterns using searchlight analysis delineated behavior-related neural activity with a peak in high-level ventral visual cortex. Comparison of behavior with MEG sensor patterns revealed the time course of behavior-related activity, peaking at 200ms. Further analyses showed that these were neither fully explained by capturing the categorical structure of the image set, nor by representations in current deep neural networks trained in object perception15. Finally, behavior-constrained fusion of MEG with fMRI data by RSA revealed the spatio-temporal dynamics of behavior-related activity as a subset of all visual activity during visual processing, In sum, these results elucidate the relation between neural activity and human behavior in visual object recognition. By showing that this relation is not fully captured by categorization or current categorization-based models of vision, it highlights the role of perceptual aspects in the representations of objects in the human brain.

Acknowledgement: DFG Emmy Noether Grant to RMC (CI 241/1-1)

63.4056 **MEG decoding reveals the representational dynamics of task context in visual processing** Martin Hebart[1](martin.hebart@nih.gov), Brett Bankson[1], Assaf Harel[2], Chris Baker[1,4], Radoslaw Cichy[3,4]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health, National Institute of Health, [2]Department of Psychology, Wright State University, [3]Department of Psychology and Education, Free University Berlin, [4]contributed equally

We are constantly faced with goals that require us to process the same visual stimuli according to different task demands. While much attention has been paid to the perceptual processing of visual stimuli, much less is known about the processing of the task context in which these stimuli occur. Here we used MEG to study the temporal evolution of task representations and their effect on visual category processing. During MEG recordings, participants (N = 17) were shown 8 visually-presented objects embedded in one of four task contexts. Multivariate classification was carried out in a time-resolved manner both for task and category. We found that after presentation of the object stimulus, object information increased rapidly as expected. In contrast, task information increased relatively slowly, peaking around 500 ms post stimulus onset. Using temporal cross-classification, we demonstrate that task context is processed in multiple, distinguishable but partially overlapping stages. To better understand the spatial distribution of task and category information, we used model-based MEG-fMRI fusion (Cichy et al., 2014, Nat. Neurosci.) by combining our MEG data with the results of a previous fMRI study (Harel et al., 2014, PNAS). While early visual cortex exhibited preferential processing of stimulus information and lateral prefrontal cortex preferential processing of task context, we found co-varying task and category information in ventral temporal cortex, indicating that task context may affect visual processing in these brain regions. Together, our results reveal a relatively late involvement of task context in visual processing and highlight the representational dynamics of task context.

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63.4057 **Revealing the temporal dynamics of individually unique object representations** Ian Charest[1](i.charest@bham.ac.uk), Daniel Lindh[1,2], Sara Assecondi[1], Matthias Treder[1]; [1]School of Psychology, University of Birmingham, UK, [2]Department of Psychology, University of Amsterdam, Netherlands

Using Representational Similarity Analysis (RSA) and fMRI, we recently demonstrated evidence for individually unique visual object representations that predict perceived similarity (Charest et al. 2014). To date, little is known about how such idiosyncratic representations are established in the brain when perceiving an object. RSA analyses of MEG/EEG data provide novel opportunities to track brain representations with high temporal precision. To this end, we recorded 128-channel high-density EEG while participants (n=20) were presented with personally-meaningful and unfamiliar object images. These included pictures of bodies, faces, places, and man-made objects. We trained a Fisher linear discriminant on spatial features in order to classify each image pair. These pairwise decoding accuracies form entries in "representational dissimilarity matrices" (RDMs), which characterise the representational geometry at each time point. The average decoding performance that we observed using EEG is comparable to previous MEG results (Cichy et al. 2014), with significant image decoding from ~70ms post-stimulus onset and peak decoding at ~150ms. To measure the reliability of representational geometries, we computed the RDM replicabilities (correlation between lower-triangular entries) across data-splits at each time point. We observed replicable RDMs from ~80ms post-stimulus onset which carried over a sustained time window. Comparing dissimilarity matrices at each time-point within and between individuals revealed the neural dynamics of individually unique object representations. Importantly, we found earlier individuation effects for unfamiliar compared to personally-meaningful images. This is consistent with our previous fMRI results where an individuation effect was observed in early visual cortex only for unfamiliar images. In summary, successful image decoding suggests rich spatial information contained in EEG topographies characterising stable object representations. Furthermore, harnessing the temporal precision offered by EEG, we reveal an interaction between early visual processes and personally meaningful objects. Using MVPA applied to EEG enables to characterise the build-up of idiosyncratic object representations.

63.4058 **Comparing human and convolutional neural network performance on scene segmentation** Noor Seijdel[1](N.seijdel@uva.nl), Max Losch [1], Edward De haan [1], Steven Scholte[1]; [1]Brain and Cognition, Psychology, University of Amsterdam

The most recent variations of convolutional neural networks (ConvNets) have managed to match and surpass human performance on classification of objects in images (Russakovsky et al., 2015; He et al., 2015). An open question remains whether humans and ConvNets process visual information in a similar fashion. It is known that humans perform object recognition best under certain conditions: e.g. when the object is shown in the canonical view (often three-quarter view) and when the object is presented on a homogenous background. In the current study we compare human and computer model performance on those different levels. Carrying forward the object classification task, we manipulate the relationship between object and background by presenting 3D models of objects A) in isolation, B) with a congruent background and C) with an incongruent background. Finally, we manipulate the viewpoint by presenting these 3D models of objects in different angles. We evaluate the performance of 40 human subjects with that of ConvNets with different depth and complexity. Preliminary results indicate an important, implicit, function of depth in CNN's to segregate the object from the scene. Overall, comparing the performance of humans and computer models on these more specific or detailed tasks will give a more fine-grained view of the similarity between both and could link more cognitive descriptions of behavior to ConvNets.

63.4059 **Relational processing of abstractly and associatively related object pairs: an ERP study** Leemor Zucker[1](leemorzucker@mail.tau.ac.il), Liad Mudrik[1]; [1]Tel Aviv University

A major challenge in the study of human cognition is understanding the mechanisms of semantic integration (SI). SI denotes the ability to judge semantic relations and form new meanings (e.g., for associative relations, "mirrors tend to co-occur with hairbrushes"). Though much research has been devoted to the way concepts are encoded and organized in the brain, little is known about the way the relations between such concepts are processed, especially when these relations do not rest on associative knowledge (e.g., "mirrors and peacocks both convey the concept of vanity"). Here we asked whether such abstract SI rests on the same neural mechanisms as associative SI, by assessing whether these processes differ in a quantitative or a qualitative manner. We contrasted ERPs induced by abstractly related, associatively related and unrelated pairs of concrete, real-life objects, presented sequentially. Subjects' task was to determine whether the objects were related and rate the strength of these relations. As expected, performance was less accurate and slower for abstract than associative or unrelated pairs, and ratings of relations strength decreased from associatively related, through abstractly related to unrelated pairs. Electrophysiological measures supported both a quantitative and a qualitative difference between abstract and associative pairs: the amplitude of the N400 component, held to index SI, was quantitatively modulated by semantic relations type. Notably, abstract pairs also elicited greater right over left hemisphere acitvations than associatively related pairs, suggesting a greater role for right areas in abstract relations processing.

Acknowledgement: ISF

63.4060 **Oscillatory signatures of object recognition across cortical space and time.** Leila Reddy[1,2](leila.reddy@gmail.com), Radoslaw Cichy[3], Rufin VanRullen[1,2]; [1]Université de Toulouse UPS Centre de Recherche Cerveau et Cognition 31052 Toulouse, France, [2]CNRS CerCo 31052 Toulouse France, [3]Department of Education and Psychology, Free University Berlin, Berlin, Germany

Numerous theories propose a key role for brain oscillations in visual perception. Most of these postulate that sensory information is encoded in specific oscillatory components (e.g., power or phase) of specific frequency bands. These theories are often tested with whole-brain recording methods of low spatial resolution (EEG or MEG) or in depth recordings (LFP) that provide a local, incomplete view of the brain. Opportunities to bridge the gap between local neural populations and whole-brain signals are rare. Here, using representational similarity analysis (RSA) between separate MEG and fMRI datasets we systematically explored the correspondence between whole-brain oscillatory signals and local activity in specific brain regions (V1 and IT). Fifteen subjects were tested with MEG and fMRI while they viewed 92 different objects. Time-frequency (TF) analysis for each trial and MEG sensor was performed. Two oscillatory components (power and phase) were extracted at each TF coordinate. MEG representational dissimilarity matrices (RDMs) were computed for the two oscillatory measures at each TF coordinate, and fMRI-RDMs were computed for V1 and IT. Finally, RSA was performed between the MEG- and fMRI-RDMs. The RSA showed that at stimulus onset, most oscillatory signals correlated first with V1, and then with IT representations. However, later in the trial, different brain areas simultaneously carried stimulus information, but in different frequency bands (e.g., about 50ms prior to stimulus offset, high-beta 20-32Hz oscillations resembled V1 activity, while the theta 4-8Hz band resembled IT). Additionally, stimulus information in different oscillatory components at a specific frequency could simultaneously match representations from different brain regions (e.g., in the beta 13-20Hz band around 300ms, information in oscillatory power more resembled V1, while oscillatory phase information at the same time points more resembled IT). These results set the stage for a systematic understanding of the relation between whole-brain oscillatory signals and local neuronal activations.

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63.4061 Do inverted scenes modulate semantic object processing? Behavioral and electrophysiological insights

Tim Lauer[1](lauer-tim@stud.uni-frankfurt.de), Verena Willenbockel[1], Melissa Vo[1]; [1]Scene Grammar Lab, Goethe University Frankfurt

Objects presented in semantically related contexts are better recognized than in unrelated surroundings. What information of a scene yields this facilitative consistency effect? Here, we investigated whether seeing scenes in an unfamiliar orientation (rotated 180 degrees in the picture-plane) modulates the semantic processing of superimposed objects. We paired indoor and outdoor scenes with either an indoor or an outdoor thumbnail object to manipulate semantic consistency. We then presented either consistent or inconsistent upright thumbnail objects on three types of backgrounds: upright scenes, inverted scenes, and scrambled scenes (control condition). In Experiment 1, stimuli were gray-scale and the critical object was presented for 56 ms centered on the background image followed by a dynamic mask. Participants were instructed to name the object, while the background image was task-irrelevant. On upright scenes, consistent objects were named more accurately than inconsistent objects. Inverted scenes showed only a non-significant trend in the same direction, whereas the control condition did not show any difference. In Experiment 2, participants saw the same stimuli in color for 2000 ms each and completed a repetition detection task with both objects and backgrounds. We recorded event-related potentials (ERPs) as a possibly more sensitive measure to specifically look at the N400 component, which has originally been linked to semantic access in language processing and more recently also in scene perception. If inverted scenes indeed modulate semantic object processing they should elicit more negative ERPs to inconsistent than to consistent objects. While inconsistent versus consistent objects on upright scenes triggered a frontal negativity in the N400 time window (350-600 ms), neither inverted scenes nor control images elicited differential ERPs in this N400 time window. Together, our behavioral and electrophysiological data suggests that scene inversion - which preserves low-level image properties (except for phase) - highly limits contextual influences on semantic object processing.

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63.4062 Carving up the ventral stream with Deep Synthesis

Anthony Norcia[1](amnorcia@stanford.edu), Wesley Meredith[1], Guillaume Reisen[2], Daniel Yamins[1,3]; [1]Department of Psychology, Stanford University, [2]Neuroscience Graduate Program, Stanford University, [3]Department of Computer Science, Stanford University

A prominent working hypothesis about object recognition is that an increasingly rich representation of natural images is constructed by a hierarchically organized series of processing steps. An especially efficient means to explore this hypothesis is to invert an image-computable encoding model to synthesize image metamers, pairs of images that are statistically equivalent up to a given level of statistical regularity. This idea has been usefully deployed in early visual areas, using a two-layer hierarchical model to differentiate visual area V1 from V2 (Portilla and Simoncelli, 2000; Freeman and Simoncelli, 2011). Inspired by Gatys et al., (2015), we generalized the synthetic metamer approach to probe higher levels within the ventral stream. Specifically, using a Deep Neural Network that has been shown to predict neural responses in multiple ventral stream areas (Hong et al., 2016), we create a graded series of 5 metamers with increasing fidelity to the high-level statistics of intact natural images. Using these stimuli, we measured Steady-State Visual Evoked Potentials (SSVEPs) to alternations of the original images with corresponding synthesized images drawn from each of the 5 levels of the synthesis stack. Metamerism was operationalized as the magnitude of the first harmonic of the SSVEP, a response component that quantifies the differential response between synthesized and original images. SSVEP amplitude scaled in proportion to the distance between the highest layer included in the synthesis and the original image (n=16 adults). The phase of the SSVEP, a measure of processing delay, also showed progressively delayed responses for images drawn from increasingly higher layers of the synthesis stack, consistent with a temporal processing hierarchy that is based on the statistical complexity of the images. Deep Neural Networks provide tunable generative models of images that can be used to test specific hypotheses about complex levels of processing in object recognition pathways.

63.4063 Elucidating Mechanisms of TMS-induced Visual Suppression

Evan Center[1](ecenter2@illinois.edu), Monica Fabiani[1], Gabriele Gratton[1], Diane Beck[1]; [1]University of Illinois at Urbana-Champaign

Transcranial magnetic stimulation (TMS) visual suppression refers to poorer visual detection or discrimination performance during a specific interval when single-pulse TMS is applied over occipital cortex; typically such suppression is observed in an 80-100ms post-stimulus interval. Drawing on retino-cortical transmission time estimates, some have proposed that TMS is interfering with feedback or recurrent processing in the visual stream. However, there is considerable variability in cortical transmission times across stimuli. Thus, in order to test the feedback hypothesis, both a measure of cortical transmission time and a measure of visual suppression are needed for identical stimuli and subjects. This project seeks to be the first to accomplish exactly that. Cortical transmission time is estimated using the C1 event-related potential (ERP) component, while in another session the same subjects undergo TMS pulses of variable lags (0-176 ms post-stimulus) used to suppress the same stimuli that elicited the C1. The difference in time between the C1 ERP component latency and optimal suppression point latency within subjects, aided by known estimates of cortico-cortical transmission times, allows for differentiation between competing hypotheses of feedforward or feedback mechanisms of TMS-induced visual suppression. Preliminary results evidence a window of time between peak C1 activity and peak suppression that is too small to support an account positing interruption of feedback/recurrent processes, and instead suggests interruption of the feedforward signal.

63.4064 Developmental visual perception deficits in the presence of adeqaute face perception but abnormal eye movements

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Visual categories are associated with eccentricity biases in high-order visual cortex: faces and reading with foveally-biased regions, while common objects and space with mid and peripherally-¬biased regions. As face perception and reading are among the most challenging human visual skills, and are often regarded as the peak achievements of a distributed neural network supporting common objects perception, it is unclear why objects are associated with mid¬ to peripheral bias rather than with a foveal bias. Here, we report about a 9 y.o. boy (BN) with developmental object and space perceptual deficits resembling object agnosia, but with seemingly adequate face perception, and with acquired reading skills.

Given BN's normal basic level vision, but significantly impaired oculomotor pursuit and saccades, we raise the possibility that pursuit and saccades play a critical role in the development of normal object and space perception, but less so in face perception or reading. As common objects and space prevail in mid to peripheral visual field, we raise the possibility that normal development of object and space perception might rely on normal eye movements that allow drawing foveal vision to them.

Multisensory: Cognition, clinical and synesthesia

Wednesday, May 24, 8:30 - 12:30 pm
Poster Session, Pavilion Posters 5

63.4065 Influence of Expectation on McGurk Effect

Nikki Buzdar[1](n_buzdar@csu.fullerton.edu), Brittney Hernandez[1], Alexander Le[1], Moire Sigler[1], Eriko Self[1]; [1]Department of Psychology, California State University, Fullerton

McGurk effect is a multisensory illusion in which one perceives another consonant when the audio recording of a consonant is presented with visual image of a different consonant. For example, auditory "ga" stimulus combined with visual "ba" stimulus may result in perception of "da." Frequency of McGurk effect experience may be affected by many factors such as expectations, general sensory preference, and sensory system efficiency. There are also large differences among individuals in the rate of McGurk effect occurrence. The goal of this study was to investigate the influence of the context which manipulates participants' expectation on McGurk effect. We used 4 types of contexts: neutral (black screen), congruent (auditory and visual stimuli show the same syllabi), incongruent (auditory and visual stimuli show different syllabi), and mismatch (auditory syllabi are combined with video in which a speaker reads sentences). The duration of the context was 2 sec for neutral context, and 1, 2, 4, or 8 syllabi for the other contexts. After the context stimulus, a gray screen was presented for 1 sec before the target stimulus. The target stimulus was either normal audio-visual video (auditory and visual components show the same syllable twice) or McGurk stimulus (auditory and visual components are created in one of the combinations that are known to produce McGurk effect; the same combination of the syllable is repeated twice). The participant indicated the perceived syllable (consonant) by a button press. The order of the context type and the target stimulus type were randomized. Surprisingly, the results did not show a significant effect of the context type on McGurk percept. On the other hand, there was a significant effect of context duration such that the four-syllable context produced less frequent McGurk percept compared to shorter or longer contexts.

63.4066 The Neural Correlates of Cross-Modal Category Learning

You Li[1], Ying Fang[1], Hui Li[1], Nan Liu[1], Yizhou Jiang[1], Lei Mo[1], Qi Chen[1]; [1]Center for Studies of Psychological Application and School of Psychology, South China Normal University

Category learning is an essential cognitive function for human survival which receives sustained attention from psychologists. Although category learning has been studied extensively, however, in nearly all cases, the stimulus dimensions are processed within the same sensory modality, for example, vision. In reality, the human brain constantly integrates information from different modalities. Behavioral studies documented the human's ability to learn cross-modal categories (Maddox, Ing, & Lauritzen, 2006; Smith et al., 2014). An open question remains that: What is the neural mechanism underpinning cross-modal information-integration (II) category leaning? Aiming at answering this question, this study adopted functional magnetic resonance imaging technique to investigate the neural correlates of cross-modal category learning. Participants (n = 19) learned to categorize two sets of II categories, sequentially. For the cross-modal categories, exemplars were conjoint visual-auditory stimuli, each composed of a Gabor varied in orientation and a pure tone varied in pitch. Successful categorization required integrating information across the visual and auditory modalities. For the within-modal categories, only Gabors varied in orientation and spatial frequency were used, which required within-modal information integration. For each set, a control color judgment task was performed with the identical stimuli. Behavioral results showed equivalent categorization performance for cross- and within-modal category learning, suggesting that participants could solve the II category tasks by integrating information across two sensory modalities. Imaging results showed that, compared with within-modal categorization, cross-modal categorization specifically recruited the fronto-insular cortex in the PFC, and the SMA. In addition, during cross-modal categorization, there was significantly enhanced neural coupling between the visual cortex and the auditory cortex. Taken together, the results of this study reveals the neural mechanism underpinning cross-modal category learning, which suggests extension of existing category-learning models.

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63.4067 Combining linguistic and visual instructions in a virtual reality maze.

Serena De Stefani[1](serena.destefani@rutgers.edu), Eileen Kowler[1], Karin Stromswold[1], Shahan Akhter[1], Jacob Feldman[1]; [1]Rutgers University

Human spatiotemporal reasoning and problem-solving rest on the effortless encoding of perceptual and linguistic cues. The integration of cues across visual and linguistic domains is relatively understudied, and is particularly challenging because the two sources have such potentially different interpretations or presumed reliability. When making decisions in real time, how do we combine cues coming from linguistic and visual sources? Which cue is more important and how do we resolve potential conflicts? In a first study we asked participants to navigate though eight virtual reality mazes using the Oculus Rift Headset. A single maze comprised 30 T-intersections, each presenting a binary choice (go left or right). As participants approached each intersection, they were presented with either a visual cue (a red arrow) or an auditory cue (a voice saying "Go right" or "Go left"). Four mazes displayed only visual cues with varying levels of reliability (either 10%, 30%, 50% or 70% reliability, thus including cases where cues were "reversed"), while the other four mazes displayed only auditory cues with analogous levels of reliability. We recorded the proportion of trials on which cues were "trusted" (participants followed the indicated direction) under different conditions. Results show a higher level of trust for voice cues compared to arrow cues and a marked drop in trust at 10% reliability, while the other trust levels appear clustered together. A second study had a similar setup except that both visual and auditory cues were displayed, with either matching or different reliability levels (either 20%, 50% or 80% reliability). Again, subjects tended to trust linguistic cues more than visual ones, despite the objectively matched reliability levels. We also found a number of more subtle interactions between cue type and reliability learning, suggesting a complex integrative process underlying real-time decision-making.

63.4068 Cross-Modal Entrainment in Visual Working Memory and Eye Movements

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Rhythmic stimuli can entrain cortical oscillations and facilitate the processing of information presented at predictable moments in time. Recent data suggest that these effects may be cross-modal: participants respond faster to visual targets presented in sync with an auditory rhythm. In a series of three experiments we first asked whether the effects of rhythmic auditory stimuli on visual processing extend to their encoding into visual working memory (VWM). In Experiment 1, participants heard a series of 10 periodic tones (tone onset interval = 600ms). Following the sequence, an array of 3 or 5 colored squares appeared and participants were instructed to remember the locations and colors of the squares. The interval between the last tone and the array was 523, 600, or 676ms. Participants pressed the space bar as soon as they saw the array and after 1000ms reported the color of a cued square by clicking on a color wheel. If entrainment to a periodic auditory stimulus enhances responses to visual stimuli, response times should be fastest when the tone-array interval was 600ms, rather than 523 or 676ms. However, response times decreased as the tone-array interval increased. In addition, although estimates of the precision and guessing rate of the reported color differed across set sizes, they did not vary across tone-array intervals. Dual-task interference was ruled out in Experiment 2. We next asked whether saccade latency for a visual target presented in sync with periodic auditory or visual stimuli was reduced, as in earlier research. However, in contrast to visual entrainers, saccade latencies were slower, not faster, for visual targets presented in sync with the auditory entrainer. Our results highlight the potential limitations of cross-modal entrainment. We will discuss the need for future studies to explore the degree to which rhythmic stimuli in one modality affect perceptual processing in another.

63.4069 Determining the relationship between emotion and sensory modality during stimulus localization. James Kryklywy[1](j.kryklywy@psych.ubc.ca), Emilie Ptak[1], Rebecca Todd[1,2]; [1]Deptartment of Psychology, University of British Columbia, [2]David Mowafaghian Centre for Brain Health, University of British Columbia

Considerable evidence demonstrates that the presence of emotionally salient cues can influence the representation and processing of sensory information. These cues have the ability to enhance the representation of target stimuli, as well as potentiate the effect of sensory distractors. Interestingly, such effects appear to be influenced by subtle design details, including the sensory mode of both emotional distraction and target presentation. As most studies utilize consistent modes for stimulus presentation, delineation of emotional effects between the senses remains incomplete. The current experiment employed a search paradigm in which observers localized either an auditory (beep) or visual (dot) target within a 180° sensory array (3 monitors and 13 speakers). Simultaneously, task-irrelevant positive, negative, or neutral distractors, chosen from standardized databases and matched for arousal and valence, were presented across the entire sensory field. Thus, there were four unique blocks of trials (2 target modes X 2 distractor modes) with two intra-modal and two cross-modal conditions. After presentation of individual target-distractor pairings, observers indicated target location via mouse-click on a visual semicircle array. Confidence ratings were collected on a trial-by-trial basis. Whereas effects of emotion on target localization accuracy were identified in intra-modal conditions, no effects were observed in cross-modal conditions. During intra-modal conditions, task performance was poorest (greatest angular deviation between response and target direction) for targets paired with positive distractors. Furthermore, during auditory intra-modal trials, negative emotional distractors augmented localization performance, resulting in lower angular deviation between response direction and target location. These results, which are consistent with findings indicating impaired attentional focus in positive emotional contexts, suggest that emotional competition during stimulus location acquisition may arise in early stages of sensory processing, prior to cross-modal influence. Moreover, this study highlights importance of considering subtle experimental design features when interpreting emotional-related influences on sensory processes.

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63.4070 Audiovisual integration and the temporal ventriloquism effect in amblyopia Michael Richards[1,2,3](michael.richards@mail.utoronto.ca), Herbert Goltz[1,4], Agnes Wong[1,2,4]; [1]Department of Ophthalmology & Vision Sciences, Faculty of Medicine, University of Toronto, [2]Department of Ophthalmology & Vision Sciences, The Hospital for Sick Children, Toronto, Canada, [3]Institute of Medical Science, University of Toronto, [4]Program in Neurosciences & Mental Health, The Hospital for Sick Children, Toronto, Canada

Introduction: Amblyopia is a developmental visual disorder increasingly recognized to affect multisensory integration. Previously, our lab reported that amblyopic individuals perceive audiovisual simultaneity over an extended range of signal onset asynchronies (SOA). While the reason for the broadened simultaneity window is unknown, it may represent impaired temporal integration. To test this hypothesis, we examined the temporal ventriloquism effect – a phenomenon in which visual temporal order judgment (TOJ) is normally enhanced by lagging auditory clicks. Methods: Viewing with both eyes, amblyopic (n = 8) and visually normal (n = 9) participants judged which of two vertically separated lights appeared first. SOA between the lights varied from -144 (bottom first) to 144 ms (top first) in 14 increments. Paired clicks accompanied the onset of the lights such that the first click preceded the first light, or second click lagged the second light, by 100, 200, 300, or 450 ms. A baseline condition with synchronous clicks and a unisensory visual condition were also included. Psychometric functions were fit to the data, and just noticeable difference (JND) values were calculated for the visual TOJ task. Results: In the amblyopia group, visual TOJ performance (mean JND = 47 ms) was enhanced over baseline (mean JND = 62 ms) when the second click lagged the second light by 100 ms (RM ANOVA, p = 0.025, Bonferroni adjustment). Performance was not significantly different between groups for any click condition, including baseline or unisensory visual conditions (mixed design ANOVA, p = 0.581) Conclusion: Participants with amblyopia demonstrate 1) enhanced visual TOJ performance consistent with the temporal ventriloquism effect and 2) unisensory visual TOJ performance equivalent to normal individuals. These findings suggest that the widened audiovisual simultaneity window in amblyopia is not the result of impaired capacity for temporal audiovisual integration or reduced visual temporal resolution.

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63.4071 Changes in functional activation for audiovisual stimuli in people with one eye Stefania Moro[1,2,4](smoro@yorku.ca), Sara Rafique[1,2], Ben Shachar[3], Brenda Gallie[4], Jennifer Steeves[1,2,4]; [1]Department of Psychology, York University, Toronto, Canada, [2]Centre for Vision Research, York University, Toronto, Canada, [3]Department of Biology, York University, Toronto, Canada , [4]Department of Ophthalmology and Visual Sciences, The Hospital for Sick Children, Toronto, Canada

People who have lost one eye early in life have enhanced sound localization (Hoover et al., 2011), lack visual dominance (Moro & Steeves, 2011) and integrate auditory and visual information optimally (Moro et al., 2013) compared with binocular and eye-patched viewing controls. Structurally, people with one eye have a less severe decrease in volume of the lateral geniculate nucleus contralateral to the remaining eye (Kelly et al., 2013). In addition, they have an asymmetry in medial geniculate body volume, larger in the left hemisphere compared to right, independent of which eye is removed (Moro et al., 2015). Given the existing audiovisual processing differences and structural changes in people with one eye, we investigated whether changes in functional activation for audiovisual stimuli are also present. Functional images were acquired with a 3T MRI scanner while participants were asked to observe a video of a speaker reading a story in an auditory only, visual only or audiovisual condition. A whole brain analysis to measure brain activity for auditory, visual and audiovisual stimuli was conducted in adults who had undergone early unilateral eye enucleation (surgical removal of one eye) compared to binocularly intact and eye-patched controls. People with one eye demonstrated increased activation in the auditory cortex contralateral to their removed eye for auditory stimuli and increased activation in the auditory, occipital and frontal cortex for audiovisual stimuli compared with controls. People with one eye demonstrated decreased activation in the occipital cortex contralateral to their removed eye for visual stimuli. In addition, they showed increased activation in the bilateral cuneus and fusiform gyrus ipsilateral to their removed eye for visual stimuli compared with controls. These functional changes, combined with changes in underlying neural structure provide evidence for compensatory reorganization for the loss of one half of visual inputs early in life.

63.4072 Cross-modal codification of images with auditory stimuli: a language for the visually impaired ? Takahisa Kishino[1](ruggero@yokohama-cu.ac.jp), Roberto Marchisio[2], Ruggero Micheletto[1]; [1]Graduate School of Nanobioscience, Yokohama City University, JP, [2]Hicare Research Srl, Environment Park, via Livorno 60 - Torino - Italy

What is the perception of an image ? Is it something strictly related to the physical perception of light or it is a more general process where objects characteristics can be deduced by a wide sensorial spectrum of information and then organized in something that can be understood as shape? Here, we describe a methodology to realize visual images cognition in the broader sense, by a cross-modal stimulation through the auditory channel. An original algorithm of conversion from bi-dimensional images to sounds has been established and tested on several subjects. Our results show that subjects where able to discriminate with a precision of 95% different sounds corresponding to different test geometric shapes. Moreover, after brief learning sessions on simple images, subjects where able to recognize among a group of 16 complex and never-trained images a single target by hearing its acoustical counterpart. Rate of recognition was found to depend on image characteristics, in 90% of the cases, subjects did better than choosing at random. This study contribute to the understanding of cross-modal visual perception of simple images and shapes. Also it contributes to the realization of systems that use acoustical signals to help visually impaired persons to recognize objects and improve navigation.

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63.4073 Unilateral amblyopia and the developmental calibration of sound localization

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Introduction: The quality of early visual experience is known to influence the development of sound localization ability. Sound localization is normal or enhanced in humans with early complete vision loss in one or both eyes, but diminished in those with selective loss of central vision bilaterally. In this study, we investigate sound localization ability in humans with amblyopia, a unilateral visual impairment caused by anomalous visual experience (i.e. strabismus and/or anisometropia) in early life. Methods: In Experiment 1, amblyopic (n = 14) and visually normal (n = 16) participants judged whether the second click of a pair was located to the left or right of the first. One click of each pair always occurred at the central reference position. Click position was controlled by amplitude panning between stereo speakers. Clicks were presented in darkness at 11 evenly-spaced virtual positions along the central 30 degrees of azimuth. Experiment 2 replicated Experiment 1 with amblyopic (n = 10, 5 new) and visually normal (n = 12, 8 new) participants using a horizontal array of 11 speakers. All participants passed an audiometer-based hearing screen. Just noticeable differences (JND) for auditory spatial resolution were derived from individual psychometric functions, and group differences were tested using the Mann-Whitney U test. Results: In experiment 1, the median JND for normal participants was 3.2 degrees, compared to 4.0 degrees in the amblyopia group (p = 0.028). In experiment 2, the same pattern was found, with the median JND in the normal group being 2.1 degrees compared to 3.7 degrees in the amblyopia group (p = 0.035). Conclusion: Horizontal auditory spatial resolution is diminished among people with unilateral amblyopia. The spatial uncertainty of amblyopic vision may disrupt the developmental calibration of the auditory spatial map.

Acknowledgement: Supported by grant MOP 106663 from the Canadian Institutes of Health Research (CIHR), Leaders Opportunity Fund from the Canada Foundation for Innovation (CFI), the John and Melinda Thompson Endowment Fund in Vision Neurosciences, the Department of Ophthalmology and Vision Sciences at The Hospital for Sick Children, and the Vision Science Research Program at the University of Toronto

63.4074 Examining auditory object and scene processing in early blind individuals.

Tristram Savage[1](Savaget@uw.edu), Elizabeth Huber [1], Ione Fine[1]; [1]Department of Psychology, University of Washington

Introduction: Early blind individuals show BOLD responses to a wide variety of tactile and auditory stimuli within occipital and ventro-occipital regions that are thought to be primarily visual in sighted individuals. These responses are widespread for sound vs. silence comparisons (e.g. Lewis et al., 2010), though specific task comparisons suggests 'functional specificity': e.g. selectively enhanced responses to motion in hMT+ and to Braille in the visual word form area. One possible source of these selective auditory responses is auditory belt and parabelt regions .These areas contain complex feature detectors tuned for specific combinations of behaviorally relevant frequencies that may play a crucial role in abstract, higher level sound representations. Our goal was to compare responses to naturalistic stimuli within auditory belt and parabelt (Moerel et al. 2013) and occipital cortex across early blind and sighted individuals. Methods: Using fMRI we measured responses to 56 3s naturalistic auditory scenes in 3 early blind and 4 sighted individuals. Subjects performed a trivially easy one-back task: reporting when an auditory scene was repeated. For each voxel, we found the frequency tuning profile that best predicted that voxel's BOLD response across the set of stimuli using either pRF modeling (Dumoulin et al., 2008) or a close variant previously used to estimate auditory frequency tunig (Moerel et al., 2015) in belt and parabelt regions. Results: Robust BOLD responses to sound vs. silence and/or sound vs. noise comparisons were found within primary and secondary auditory areas across all individuals. For both subject groups we could estimate frequency tuning within auditory areas using naturalistic stimuli. Surprisingly, despite robust responses in auditory cortex, we saw little evidence of auditory responses within occipital regions in early blind individuals. One possibility is that recruitment of occipital cortex only occurs when subjects are actively engaged in parsing auditory stimuli.

Acknowledgement: NIH

63.4075 The representation of acoustic space in the calcarine cortex of a blind human echolocator

Liam Norman[1](liam.norman@dur.ac.uk), Lore Thaler[1]; [1]Department of Psychology, Durham University

Echolocation is the perception of objects through sound echoes. Previous work has shown that activity in calcarine cortex correlates with echo-acoustic perception of objects in an early blind expert echolocator, and that the pattern of this activity might possibly resemble retinotopic organization for vision in sighted people (Milne, Goodale & Thaler (2013) JOV, 13(9): 1334). Here we tested if we could replicate this result in another early-blind expert echolocator. During fMRI a blind expert echolocator listened to binaural recordings of clicks and click echoes reflected from objects located at one of eight positions along the horizontal meridian (i.e. 5°, 10°, 20° or 40° to the right or left). We used cross-correlation to map neural representations of these echo-acoustic positions. We applied the same method to fMRI data acquired while the echolocator listened to source-sounds, that could also be at 5°, 10°, 20° or 40° to the right or left. For echo-acoustic locations, results showed a mapping of L10°, R5°, R20° and R40° along the left calcarine sulcus, and mapping of L10° and L40° along the right calcarine sulcus, in both HS with more peripheral locations being mapped more anteriorly. For source sound locations, results showed a mapping of R20° and R40° and along the left calcarine sulcus, and mapping of L40 and R20° along the right calcarine sulcus. We were able to confirm the validity of our analysis by also mapping representation of fingers along the central sulcus (fingers were used to press response keys during fMRI). The evidence is consistent with the idea that there is a contralateral neural representation of acoustic space in calcarine cortex of this blind echo expert, and that this representation is more pronounced for echo-acoustic than source sound locations. Furthermore, this representation might possibly resemble retinotopic organization for vision in sighted people.

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63.4076 Correspondence between synesthetic colors and ordinal colors in grapheme-color synesthesia

Daisuke Hamada[1](taisa1415@gmail.com), Hiroki Yamamoto[1], Jun Saiki[1]; [1]Graduate School of Human and Environmental Studies, Kyoto University, Japan

Grapheme-color synesthesia is a condition in which visual perception of letters induces simultaneous perception of a given color, often developed in childhood. Hamada, Yamamoto, & Saiki (2016) showed that synesthetic colors are concentrated in multiple regions in the color space, that is, they form "synesthetic color clusters". Why did these synesthetic color clusters emerge? Given that ordinal colors induced by physical stimuli is a basis of synesthetic colors, we assumed that high-sensitive ordinal colors become synesthetic colors for each synesthete in childhood. If the assumption is correct, synesthetic color clusters correspond to the high-sensitive ordinal colors. In the present study, we investigated whether color sensitivities corresponding synesthetic color clusters (clustered colors) is higher than color sensitivities not corresponding synesthetic color clusters (non-clustered colors). In addition, we investigated whether a difference of sensitivities between clustered colors and non-clustered colors are related to a difference in subjective experiences perceiving synesthetic colors. Some synesthetes termed "projectors," perceived their associated colors visually in external space." Others, termed "associators," perceived their colors in internal space, characterizing them as existing "in my mind's eye" or "in my head." Twelve synesthetes were measured thresholds of the color discrimination for clustered colors and non-clustered colors, respectively, by the Cambridge colour test. We used a regression analysis to assess the impact of the subjective experiences perceiving synesthetic colors on the difference of color thresholds between clustered colors and non-clustered colors. The analysis showed that associators were more sensitive to clustered colors than non-clustered colors. In contrast, projectors were more sensitive to non-clustered colors than clustered colors. This finding suggests the possibility that high-sensitive ordinal colors become synesthetic colors, but in projectors, the visual experience of synesthetic colors in everyday life from childhood leads to decrease the color sensitivity of clustered colors, as "adaptation" decreases sensitivities of stimuli.

63.4077 Red Eight, Green Eight: Color Shifts in Synesthesia

Alison Hochman[1](alison.hochman.943@my.csun.edu), Jasmine Awad[1], Rebecca Esquenazi[1], Arthur Ilnicki[1], Stefanie Drew[1,2]; [1]Psychology, Social and Behavioral Sciences, California State University Northridge , [2]Cognitive Sciences, University of California Irvine

Introduction: Synesthesia is a condition in which a single stimulus elicits multisensory perception. This is a case study investigating the experiences of a grapheme-color synesthete, Subject 1 (S1), who perceives a color when presented with achromatic letters or numbers. Many studies support the notion that synesthesia remains consistent over time. This is also referred to as the 'gold standard' (Barron-Cohen et al., 1996; Rich et al., 2005; Ward & Simmer, 2005). In our previous study examining bidirectional effects in grapheme-color synesthesia, S1 reported inconsistencies in her perception over a period of two years. This prompted further examination. Method: As a preliminary step for both the pilot and subsequent experiment, S1 completed the online Synesthesia Battery exam developed by Eagleman et al. (2007) in April 2013 and again in June 2015. Similarly, we measured S1's synesthetic color perceptions in the lab each time using the MATLAB Synesthesia Toolkit (Eagleman et al., 2007). Results: Upon reviewing S1's color perception responses, inconsistencies were noted on the Synesthetic battery exam and the Synesthesia Toolkit responses. S1 gained percepts and lost percepts between tests, and the color induced for the grapheme "8" changed from red to green between the pilot and subsequent experiment. Discussion: Our study reports a synesthete, who was highly accurate when tested using her color percepts in 2013 and 2015, having temporally inconsistent reported colors. Examining synesthetes who experience changes such as this could improve understanding of synesthesia and its underlying neurological mechanisms.

63.4078 **Grapheme-color associations can immediately transfer to novel graphemes, but such synesthetic colors are unstable.**

Kazuhiko Yokosawa[1], Takuya Tsushiro[1], Michiko Asano[2]; [1]The University of Tokyo, [2]Rikkyo University

Previous research on grapheme-color synesthesia has revealed that synesthetic colors associated with graphemes since early childhood can be transferred to a novel grapheme after only a 10-minute writing exercise (Mroczko, Metzinger, Singer, & Nikolić, 2009). The present study examined the stability of such newly acquired grapheme-color associations for novel graphemes. Participants were eight adult Japanese-speaking grapheme-color synesthetes. They learned six novel graphemes (Glagolitic alphabets); each of these graphemes was randomly paired with a grapheme acquired in early childhood (Japanese phonetic Hiragana characters). Resulting novel-familiar grapheme pairs were presented for training in a 30 minute learning session consisting of a handwriting phase and a succeeding computer-based training phase. Another set of six novel (Glagolitic) graphemes served as control stimuli; these stimuli were not associated with familiar graphemes and they did not appear in the learning session. Synesthetes selected a color experienced for each of the 12 novel graphemes from a color palette; this occurred three times: before, immediately after, and one week after the learning session. Participants were asked to indicate if they experienced no color for the grapheme. Results showed that: (1) Learned novel graphemes tended to elicit synesthetic colors more than control graphemes. In many cases the synesthetic colors for learned novel graphemes were transferred from paired familiar graphemes to these newly learned items. (2) Over a week, newly acquired synesthetic colors were subject to change, although they did not disappear. Grapheme-color matching consistency over time between measurements immediately after learning and one week after the learning for learned novel graphemes was lower than those for familiar graphemes. Collectively, the present findings suggest that although grapheme-color associations can immediately transfer to novel graphemes, such synesthetic colors are less stable than those for graphemes acquired in early childhood.

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63.4079 **Seeing sounds after visual loss: a case study of the neural correlates of acquired auditory-visual synesthesia**

Zixin Yong[1](y.z@u.duke.nus.edu), Po-Jang Hsieh[1], Dan Milea[1,2,3]; [1]Duke-NUS Medical School, [2]Singapore National Eye Centre, [3]Singapore Eye Research Institute

In a small proportion of patients who suffered from visual loss, certain auditory stimulation automatically triggers visual experience. These acquired auditory-visual synesthesia (AVS) cases are under-reported and the underlying mechanism remains elusive. In this study, we used fMRI to explore brain regions that correlated with sound-induced visual experience in an acquired AVS case, where the patient started to experience phosphenes triggered by unexpected sound after unilateral visual loss due to optic neuropathy. During the fMRI session, 1-s pure tones at various pitches were presented to the patient, who was asked to report occurrence of sound-induced phosphenes by pressing one of two buttons for yes/no response. The brain activation during phosphene-experienced trials was contrasted with non-phosphene trials. Bilateral primary and secondary visual cortex activations were observed, in addition to response-related motor area activation. To control for attention and motor-related brain activations, one healthy participant underwent a similar fMRI protocol. The participant was made to believe that light would be flashed in certain trials together with the 1-s pure tone (no flash was actually presented), and was required to guess by pressing the buttons while his eyes remained closed. In this case, only motor area activation was observed by contrasting the yes/no trials. Our results demonstrate that sound-induced visual experience in acquired AVS was correlated with bilateral primary and secondary visual cortex activation. The activation possibly occurs because of existing auditory-visual connections being unmasked after visual deafferentation.

Perceptual Organization: Contours and surfaces

Wednesday, May 24, 8:30 - 12:30 pm

Poster Session, Pavilion Posters 6

63.4080 **Equivalent internal noise for contour integration**

Alex Baldwin[1](alexsbaldwin@googlemail.com), Minnie Fu[1], Reza Farivar[1], Robert Hess[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University

Oriented wavelets give the percept of a contour if each wavelet has the appropriate position and orientation to belong to that contour. The rules governing this have been tested using a contour integration task: observers detect a contour of aligned wavelets buried in a background noise of randomly-oriented wavelets. Here we present a new threshold contour task that does not rely on a background noise field to limit performance. Observers discriminate which of four contours (at an eccentricity of 2.8 degrees in four quadrants) contains the appropriate conjunction of (6 c/deg log-Gabor) wavelet positions and orientations to feature "good continuation". The other three contours have orientations appropriate to the opposite direction of curvature. Thresholds are measured as a function of curvature (straighter contours are more difficult). By corrupting the orientation and position of the individual wavelets with external noise we measured noise masking functions. Both orientation and position noise elevated thresholds. Equivalent internal noise values were compared to those from tasks where observers made judgements about single elements. We found that in a contour the orientation noise was elevated (260%) but the position noise was reduced (40%). This suggests that contour processing privileges the refinement of position information at the expense of orientation. The sensitivity loss between 4 and 8 degrees of eccentricity was modest (10% threshold increase), and was abolished when the scale of the contours was doubled in the periphery. In another experiment, we introduced a "baseline" curvature to the stimuli to investigate discrimination of curvier contours. Thresholds were elevated relative to discrimination of straighter contours (190%). Contrary to results from the previous contour task, we found observers could integrate curvy contours in the periphery. The measurements from this novel paradigm could be used to investigate mid-level visual impairments, and to constrain models of the traditional contour task.

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63.4081 **Edge Detection through Kinetic Occlusion: The Role of Spatial and Temporal Integration**

Benjamin Miller[1](bmill007@ucr.edu), George Andersen[1]; [1]Psychology, University of California Riverside

Kinetic occlusion in visual scenes is a crucial source of information that allows us to successfully perceive objects and navigate the environment. In the current study we examined kinetic occlusion's role in the perception of curved edge boundaries. Previous work (Andersen and Cortese, 1989) had suggested that the spatial information provided by kinetic occlusion was a more critical factor in the perception of shapes than temporal information, so we sought to determine if the same was true for the discrimination of edges. Participants were presented pairs of displays with opaque objects occluding a moving background texture and asked to determine which of the two objects had a curved edge. Thresholds for curvature sensitivity were derived using a QUEST adaptive staircase procedure in a four (density of background texture) by four (velocity of background texture) design. Results indicated a main effect for both density of background texture elements and velocity of the moving texture. As either factor increased participants' sensitivity to curvature increased. A significant density by velocity interaction was also found, indicating a multi-

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plicative effect of increasing one factor as the other increased. The effect of rate of accretion and deletion of texture was also separately analyzed. Surprisingly the analyses indicated that there were no significant differences between conditions that had the same rates of accretion and deletion. This would suggest that spatial information was not more important than temporal information. This finding suggests that the manner in which temporal and spatial information is integrated is different when trying to extract edge boundaries as compared to overall shape of an object.

63.4082 Contour interpolation: A case study in Modularity of Mind

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In his book Modularity of Mind (1983), Jerry Fodor postulated perceptual and linguistic mechanisms that draw upon a limited range of stored information to execute specialized operations. Do modules exist? There have been hundreds of articles on the topic, but debates thus far have been framed in very general terms without any detailed case studies. The topic is important not just because of its historical interest but also because it provides a viable overarching framework from which to further understand and make hypotheses about the mind's structure and function. Here, I consider the modular nature ("modularity") of contour interpolation, which is a visual process that represents non-visible edges on the basis of how surrounding visible edges are spatiotemporally configured. Interpolation is examined because it is a prima facie likely candidate: it helps recover fundamental scene characteristics like object shape, number and persistence; it is phylogenetically primitive, appearing throughout the animal kingdom; and it impressively determines at each moment how hundreds of scene segments form contours and closed surfaces (objects). I argue that interpolation qualifies as a module in Fodor's original sense of the term. I present evidence that interpolation is domain specific, mandatory, fast, and developmentally well-sequenced; that it produces representationally impoverished outputs; that it relies upon a relatively fixed neural architecture that can be selectively impaired; that it is encapsulated from belief and expectation; and that its inner workings cannot be fathomed through conscious introspection. Upon describing results that are seemingly inconsistent with a modular interpolation process, I argue that interpolation is modular to the extent that the initiating conditions for interpolation are strong. As interpolated contours become more salient, the modularity features emerge. It is concluded that the empirical evidence, taken as whole, confirms Fodor's original speculation that at least certain parts of the mind are modularly organized.

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63.4083 Poorer contour integration occurs in students with positive schizotypy

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Schizophrenia patients exhibit poor contour integration on the Jittered Orientation Visual Integration (JOVI) task even at the first episode of illness, but little is known about visual integration abilities prior to illness onset. Here we examined if similar difficulties occur in healthy individuals prone to psychosis. We used a modified JOVI task – the Radial Frequency Jittered Orientation Tolerance (RFJOT) task - in students with high (n = 59) and low (n = 80) positive schizotypy traits, a risk marker for schizophrenia. For this task, the observer decides whether a spatially sampled contour present in a field of Gabor patches is left-ward or right-ward pointing. As the orientation jitter of sampled patches changes (0o, 7o, 11o, 15o, 19o, 23o, 27o), the stimulus becomes more difficult to see, with thresholds representing the amount of jitter that causes performance to decline to 75% accuracy. Participants were given an infinite amount of time to respond, in order to dissociate integration ability from individual differences in processing speed. There were no significant group differences at 0o jitter, which suggests attention to the task was adequate regardless of schizotypy status. However, compared to the low schizotypy group, the high schizotypy group had a significantly lower proportion of correct responses, collapsed across non-zero jitter levels, and significantly lower thresholds, with medium effect sizes for both outcomes. The results indicate that poorer contour integration occurs in high positive schizotypes who are at increased risk for schizophrenia. These findings add to extensive evidence of visual integration dysfunction in schizophrenia, and suggest that similar difficulties may be present prior to first diagnosis, i.e. poor contour integration represents a trait marker of schizophrenia. The RFJOT task may offer a useful measure of visual integration, indexing risk for schizophrenia, in general community samples.

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63.4084 Modifying perceptual rules for surface representation with perceptual learning

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Two-dimensional retinal images are ambiguous about the 3-D configurations of real-world surfaces/objects. For example, a square surface juxtaposed with an L-shaped target (L-coplanar condition) could either be perceived as a square and an L, or two overlapping square surfaces due to partial occlusion. The latter surface representation is often preferred due to the visual system's past experience of learning to use T-junction information for image segmentation that renders the L-shaped target in back, leading it to be represented as an occluded square (amodal completion). Additionally, if one renders the L-shaped target in back with uncrossed binocular disparity (L-back condition), a bottom-up depth cue, the tendency to see the L-shaped target as a partially occluded square is increased. Only if one renders the L-shaped target in front using crossed disparity (L-front condition) is the L-shaped target unambiguously seen as an L. Using such stimuli, He & Nakayama (1992) found that observers took longer to find the "L" in the L-back condition than the L-front condition in a visual search task. This is because the L-back search elements had T-junctions and binocular disparity cues, leading the visual system to interpret the L-shapes as partially occluded squares according to its internal perceptual rule. Here, we investigated if the perceptual rule (T-junction) could be modified if we compel the visual system to search for the L-shaped target (task specific learning). We did this by having observers perform roughly 15,000 trials of visual search trials with the L-coplanar condition. We found search time improved, with the L-coplanar and L-front RTs becoming similar. However, search in the L-back condition remained slower. This suggests that with task specific learning, the visual system can learn to discount T-junction information (experiential knowledge) for image segmentation, but that it is harder to discount binocular disparity information (bottom-up).

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63.4085 Perceptual surface completion and surface stability

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Using boundary contour (BC) information for image segmentation and surface representation is the purview of the BC-based image segmentation mechanism. A critical function of the BC-mechanism is contour completion. Both local signals, e.g., contrast, orientation, junctions and binocular disparity, as well as global spatial relationships provide cues for surface completion. However, few psychophysical studies have quantitatively measured how these cues affect surface completion and the stability of the represented surface. To investigate this, we presented a pair of silhouette rectangular gray bars to the observers. The bars intersected in the middle and crossed one another at an angle of either 45 deg or 90 deg apart (e.g., 0/90, 45/135 and 45/90 deg). Each bar moved along its long axis at 0.6 deg/sec. This arrangement allowed us to measure surface completion, as the stimulus induced an alternating percept of one or the other bar being seen in front, carrying along with it a pair of subjective contours of the front bar at the intersection. Observers perceptually tracked their perception of the subjective contours for 30 sec. This allowed us to obtain the predominance of seeing each bar in front (proportion of dominance duration). We found the predominance for seeing the vertical bar was higher than for oblique or horizontal bars. We attribute this to the visual system's preference for vertical orientation, thus aiding it in the battle for modal completion. Furthermore, we found predominance was higher for a wider bar and for a bar with crossed binocular disparity, revealing these as factors influencing modal completion. Finally, we found that global spatial relationship, such as the bar's interior surface features relative to surrounding background configuration, affects predominance. Overall, our study provides a quantitative understanding of how local and global cues determine surface completion and how the weighted cue strengths affect surface stability.

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63.4086 Separating perception and recognition in amodal completion: Dot localization with regular patterns

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Background: Previously, we reported evidence that global and local effects in amodal completion reflect two different processes: a perceptual process that uses particular geometric relationships to interpolate edges under occlusion, and a global recognition process that suggests the likely shape of an object based on cues such as symmetry or familiarity but does not produce precise contour representations. These processes were distinguished experimentally using a dot localization procedure with shapes exhibiting potential familiarity or bilateral symmetry. Here, we attempt to distinguish these two processes in amodal completion of regular patterns. Method: Participants were assigned to either a local or global condition, which determined how they were instructed to complete shapes exhibiting potential radial or translational symmetry. On each trial, an occluded shape was presented, and a small red dot was flashed in front of the occluder. Subjects were asked to report whether the dot fell inside or outside of the line of sight of the interpolated boundary. Interleaved adaptive 2-up, 1-down staircases were used to estimate two points on the psychometric function: positions where the dot was .707 likely to be judged inside or .707 likely to be judged outside of the occluded object's boundaries. Imprecision (the distance between these two thresholds), location (their mean), and location error (the absolute value of deviation from predicted location) were measured. Results: Local completion produced markedly greater precision, more accurate location, and smaller location error. In addition, local subjects' responses for all measures were highly consistent with each other, while the global group demonstrated variances that were an order of magnitude larger. Conclusions: Local completion produces precise and accurate boundary representations. Global completion appears to be a cognitive registration of the possibility of a regular pattern behind an occluder; it does not, however, produce precise representations of occluded object boundaries.

63.4087 **Different Mechanisms in the interpolation of modal and amodal completion; Evidence for different involvement of lower visual areas**

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Visual objects impose fragmented contours on our retina in almost every visual scene. Yet, in most cases, humans perceive continuous surfaces and coherent objects. The two most common cases of fragmented contours are of modal (illusory contours) and amodal (partially occluded contours) completion. Despite their different phenomenology, it has been strongly argued that the same local interpolation mechanism underlies both types of perceptual completion ('Identity Hypothesis'). Some recent studies provide evidence for distinct processes mediating the two types of completion, including differences in dependency of interpolation on geometrical factors and in their developmental rates, as well as suggestions for different involvement of cortical areas. We tested these suggestions directly exploring the involvement of lower visual areas in the interpolation of modal versus amodal completion. Subjects were asked to judge the curvature of an interpolated shape (fat or skinny) varying in degrees of support ratio (i.e., ratio of physically presented contours to interpolated contours). Stimuli were presented stereoscopy either as a whole to one eye or segregated between the eyes. Binocular disadvantage (weaker interpolation in the two eyes presentations) indicates involvement of lower visual areas in the process. The results replicated the stronger effect of support ratio on modal interpolation, and more critically, revealed a binocular disadvantage for modal but not for amodal stimuli. The results indicate two different mechanisms with modal completion involving a more local interpolation process comprising lower visual areas, while amodal completion is presumably mediated by higher visual input.

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63.4088 **Depth-Dependent Misalignment in the Poggendorff Effect**

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In the Poggendorff illusion an oblique line is interrupted by a pair of parallel lines or a rectangle, resulting in an apparent misalignment of the visible ends of the oblique line. From a century and a half of experiments, it is clear that multiple factors may contribute to the phenomenon. Here we examine the role of the junctions and the interpretation of occlusion in the Poggendorff effect. In the first experiment, observers viewed a vertical rectangle (1.75 x 8 deg) and oblique line (acute angle: 30 deg) through LCD shutter glasses (frame rate: 120 Hz). On different trials, the oblique line was tilted left or right and at -3, 0, or 3 arc min of disparity with respect to the rectangle which was in the plane of the display. Observers reported whether the oblique line ends appeared aligned or not on each trial. There are two main results: i. observers were most likely to report misalignment when the oblique was in the plane of the object; ii. there was a near/far asymmetry – oblique in front of the rectangle tends to be seen as aligned, but not when behind the plane. We conclude that an important aspect of the illusion is whether the junction is interpreted as a join or not. In a second experiment we created Poggendorff variants involving intersecting rectangles and triangles, or long ellipses intersecting long ellipses. Shadows were added to one or another part of the figure to imply a depth order of the two objects. In this experiment, interrupted contours appear aligned if they are implied to be in front, but not if behind. We conclude that contour extrapolation processes work correctly unless vetoed by evidence for a join between objects. A model explaining the mechanism of junction bias will be described.

Perceptual Organization: Ensemble coding and segmentation

Wednesday, May 24, 8:30 - 12:30 pm
Poster Session, Pavilion Posters 7

63.4089 **The effect of spatial configuration and luminance polarity on visual number estimation**

Elena Gheorghiu[1](elena.gheorghiu@stir.ac.uk), Benjamin Dering[1], Claire Mitchell[1]; [1]University of Stirling, Department of Psychology, Stirling, FK9 4LA, Scotland, United Kingdom

It is known that humans can rapidly and accurately estimate small sets of items, a process referred to as subitizing. Similarly, shape recognition is rapid and accurate for simple geometric shapes. The precise but limited nature of both processes suggests that they might be mediated by common mechanisms. Here we investigate the role of spatial configuration and luminance polarity of elements on number estimation. Stimuli consisted of a small number of Gaussian blobs (3 to 6) positioned in different spatial configurations, either on the vertices of simple geometric shapes (triangle, square, pentagon, hexagon) or random. The elements were either the same or different in luminance polarity. We measured event-related potentials (ERPs), reaction times (RTs) and accuracy while participants performed a number estimation task. We found (a) faster RTs and higher accuracy when the blobs were located on simple shape configurations compared to random conditions and, when the number of elements and shape vertices were the same; (b) faster RTs with same than different luminance polarity but only for larger numbers of elements and no effect of polarity on accuracy; (c) an N2 component, around 250-400 ms over lateral occipital electrodes, that increased in amplitude for shape configurations compared to randomly placed elements; (d) an N2 mean amplitude that gradually increased with the number of elements; (e) an inhibitory effect over left mid-frontal electrode sites (termed LMFE) measured between 400-700 ms whose mean amplitude was inversely related with the number of elements; specifically, LMFE appeared to separate low (3, 4) and high (5, 6) number of elements irrespective of their shape configuration. Altogether, the performance and the graded ERP pattern of responses in the N2 range and LMFE suggest that rapid number estimation can benefit from simple shape configurations, involving a fast shape template matching process.

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63.4091 **Estimating temporal average of numerical information: digits and texture**

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Our previous investigations on the human estimation of temporal average from dynamically changing visual stimuli showed that observers often emphasize information at ~200-500 ms before decision to judge the temporal average (Sato et al., 2013, 2016). This recency effect is found for a range of visual attributes including orientation, motion direction, and facial expression. Exceptionally, when observer judge the arithmetic average of digit numbers, they equally weigh information at any temporal location over the stimulus presentation (Sato et al., 2016). In order to examine whether the lack of recency effect in the judgement on temporal average of number is specific to digits, the present study investigated human judgments on temporal average of the number of dots. Stimulus was a texture composed of white dots with maximum quantity of 2-40, and the quantity of dots at each frame was temporally varied in accordance with a Gaussian distribution with a particular mean and S.D. during the presentation of 2 sec. Observers were asked to judge whether the average number of dots was above or below a certain number. By means of a logistic reverse correlation analysis, we calculated the impact of information at each temporal frame upon the observer's response. The results revealed no recency effect again for the temporal average of dot number. This seems to indicate that numerical average over time is estimated by a common mechanism regardless of whether information was given as digits or dot textures, which is distinct from mechanisms involved in estimation of temporal average of the other visual attributes.

63.4092 **Summary statistical representation of temporal frequency** Shoko Kanaya[1,2](shoko.kanaya@berkeley.edu), Masamichi Hayashi[1,3], David Whitney[1]; [1]Department of Psychology, University of California Berkeley, [2]Graduate School of Human and Environmental Studies, Kyoto University, Japan, [3]Graduate School of Frontier Biosciences, Osaka University, Japan

Observers effortlessly extract global patterns of spatiotemporal features from multiple objects in dynamic scenes (e.g., the movement of a crowd). Studies have revealed that a variety of spatial features are efficiently integrated into ensemble representations (e.g., mean), even when displayed in temporally complex contexts. However, it is not yet clear whether the ensemble coding also applies to purely temporal features such as frequency. Here, we investigated whether the visual system can extract the mean frequency from a group of flickering objects and how many objects are integrated into this representation of ensemble temporal frequency. In the Experiment 1, the display contained four disks flickering at independent frequencies in parallel for 4 seconds. Participants reported whether the mean of display frequency was higher or lower than a subsequent single test flicker. Temporal frequencies for the display disks were extracted randomly from one of three distributions (positively-skewed, symmetric, or negatively-skewed in a range of 0.5 to 12 Hz.) Points of subjective equality (PSEs) for the estimated means significantly shifted in accordance with the means of the three distributions. In Experiment 2, we displayed a full group of 8 disks or subsets of them (1, 2, or 4 disks) and participants compared the mean of the displayed disks with the subsequent test flicker frequency. We plotted the data as a function of relative distance between the mean of all the 8 frequencies and the test flicker, and observed a trend that participants' sensitivity improved as the number of displayed disks increased, at least up to four disks. However, this effect was not very large, suggesting that participants could integrate multiple temporal frequencies and extract the mean from them, but the efficiency of integration was not as high as other low-level visual features such as size and orientation.

63.4093 **Ensemble representations account for size constancy** Sneha Suresh[1](sursn-19@rhodes.edu), Sam Thomasson[1], Jason Haberman[1]; [1]Department of Psychology, Rhodes College

The natural environment is full of redundant visual information, which the visual system compresses into an ensemble representation by averaging features of groups of items. Ensemble perception has been shown to operate with remarkable flexibility — it combines features across a host of visual domains, extracts summary information in the absence of attention, and even integrates conceptual information into an ensemble representation (e.g., Pandita, Suresh, & Haberman, VSS, 2015). In the current set of experiments, we tested whether linear perspective cues might influence the perceived average size of a group of triangles. Adding distance cues to a set of objects should cause objects in the distance to appear larger than objects without distance cues, due to size constancy. Although size constancy heuristics are well characterized, there has been limited investigation into whether the ensemble calculus takes into account the perceived size of an individual item or its physical size (e.g., Im and Chong, 2009). Observers viewed sets of triangles with and without the context of linear perspective cues and judged whether a subsequently presented test triangle was larger or smaller than the average size of the preceding set. Results revealed that observers did, in fact, take size constancy into account when estimating the average size of the three triangles. That is, observers judged the average size of triangles appearing with linear perspective cues as larger than those triangles without the cues. These results point to the remarkable flexibility of ensemble perception, which seems to incorporate both physical and conceptual representations into the ensemble code.

63.4094 **Combination of speed profile of accreting/deleting texture and occluding contour geometry in determining relative depth** Omer Daglar Tanrikulu[1](odt7@rutgers.edu), Vicky Froyen[1], Jacob Feldman[1], Manish Singh[1]; [1]Department of Psychology, Rutgers University, Center for Cognitive Science

Accretion/deletion of texture has traditionally been considered a decisive cue to ground status in determining relative depth. However, accretion/deletion can also arise from self-occlusion due to rotation in depth, and the accreting/deleting region can be perceived as figural (Froyen et al., 2013; Tanrikulu et al., 2016). Moreover, as the degree of convexity of a contour increases on one side, an accretion/deletion region is more likely to be perceived as a rotating figural object (Tanrikulu et al. 2014, 2015, VSS). In our previous studies, 3D rotation was perceived despite the constant speed of the texture. Here we manipulate the speed profile of the accreting/deleting texture, and examine its interaction with the shape of its bounding contours. In Experiment 1, a multi-region figure-ground ("rotating columns") display was used, consisting of alternating light and dark regions in which dots were moving horizontally in opposite directions. In Experiment 2, the stimuli were made more similar to traditional accretion/deletion displays, containing just two regions separated by a contour. In both experiments, we manipulated the speed profile of the dots in both sets of regions (either constant, cosine profile, or intermediate). We also manipulated the degree of piecewise convexity (part salience) of the contour(s). In both experiments, contour geometry was found to have a stronger influence on figural status than speed profile. Especially in multi-region displays, even a small convexity bias on one side largely overrode the effects of speed profile. The results underscore the importance of contour geometry—and its influence on figural status—in determining depth from motion, which most current models ignore. We present a Bayesian model, combining speed profile and contour geometry, that accounts for these findings without explicitly treating accretion/deletion as a cue to ground.

63.4095 **Unmet Expectations Impede Object Detection: Interactions Between Predictions and Error Signals Interfere with Figure-Ground Assignment** Rachel Skocypec[1](rachelskocypec@email.arizona.edu), Barnes Jannuzi[1], Kimberley Orsten-Hooge[1], Mary Peterson[1,2]; [1]Department of Psychology, University of Arizona , [2]Cognitive Science Program, University of Arizona

Do category level expectations aid object detection? Perceptual expectation effects are typically demonstrated by establishing predictions regarding particular stimuli. Here we investigate whether predictions regarding the basic level (BL) category of an object facilitate its detection. In Experiment 1, participants viewed 90-ms exposures of displays divided into two equal-area regions by a central border. A familiar object in either its upright or inverted orientation was depicted on one side of the border. We take reports of the figure on the familiar side to assay the detection of that object. To generate expectations, we presented masked words either denoting the BL name of the familiar object or an unrelated object from a different superordinate category (natural/artificial). We predicted that expectation effects would be evident if BL primes facilitate object detection. For upright displays, participants were more likely to perceive the figure on the familiar side of the border when preceded by a BL prime versus an unrelated prime ($p < .01$). Critically, comparison to a no-prime condition revealed that this effect was driven by interference from the unrelated prime. We posit that predictions established by the unrelated primes are unconfirmed and hypotheses originating from the familiar side of the display are sent forward as error signals. This mismatch impedes object detection. In Experiment 2, display duration was longer (120ms), allowing more time to resolve the mismatch. Consistent with this interpretation, unrelated primes no longer reduced reports of the figure on the familiar side of the border ($p = .87$). Thus, activating the BL category of an object doesn't facilitate object detection, at least as measured by figure assignment, which we take to be an ideal assay of object detection. Instead, we show for the first time that the mismatch, at the superordinate level, of expectations and display-generated hypotheses impedes object detection.

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Perceptual Organization: Shapes and objects

Wednesday, May 24, 8:30 - 12:30 pm
Poster Session, Pavilion Posters 8

63.4096 **Psychophysical Investigations into Skeletal Shape Representations** Nicholas Baker[1](nbaker9@ucla.edu), Philip Kellman[1]; [1]Department of Psychology, University of California, Los Angeles

Background: Abstract shape representations must support invariance across a range of 2D transformations as well as certain articulations of the shape. One prominent theory is that shape is encoded as a set of branches along axes of symmetry in the shape (Blum & Nagel, 1978; Feldman & Singh, 2013). Such a representational scheme has numerous attractive qualities, but there is relatively little psychophysical research on its psychological reality. We conducted two experiments seeking evidence for shape skeletons. Design: In Experiment 1, subjects were shown four shapes simultaneously and instructed to select the shape that differed from the other three, with no instruction about how it might differ, receiving feedback after each trial. "Same" shapes had the same number of axial branches, while the different shape had one more or one fewer. We measured subjects' ability to learn to discriminate based on branch numbers. In Experiment 2, subjects performed a same-different task on two shapes briefly presented in sequence. Each "different" trial involved one of three types of changes: metric changes preserving the shape skeleton, a change in the number of skeletal branches, or a change in the number of descendent generations. If human observers employ skeletal representations, we predicted better discrimination performance for skeleton changes than for metric changes. Results: In Experiment 1, performance on the last third of trials did not differ from performance on the first third ($p = .192$), suggesting that subjects do not learn to attend to branch number differences. However, even in the first third of trials, subjects were better than chance at selecting the different shape. In Experiment 2, subjects were better at detecting skeletal rather than metric changes that led to comparable magnitudes of contour change. Conclusion: These results suggest that skeletal shape representations may exist psychologically but are relatively inaccessible to learning mechanisms.

63.4097 Seeing structure: Perceived similarity is driven by shape skeletons

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An intrinsic part of seeing objects is seeing how similar or different they are relative to one another. This experience requires that objects be mentally represented in a common format over which such comparisons can be carried out. What is that representational format? Objects could be compared in terms of their superficial features (e.g. degree of pixel-by-pixel overlap), but a more intriguing possibility is that objects are compared according to a deeper structure. Here we explore this possibility, by asking whether visual similarity is computed using an object's shape skeleton (in particular its medial axis) — a geometric transformation that extracts an object's inferred underlying structure. Such representations have proven useful in computer vision research, but it remains unclear how much they actually matter for human visual performance. The present experiments investigated this question. Two spindly shapes appeared side-by-side, and observers simply indicated whether the shapes were the same or different. Crucially, the two shapes could vary either in their underlying skeletal structure (rather than in superficial features such as size, orientation, or internal angular separation), or instead in large surface-level ways (without changing overall skeletal organization). Discrimination was better for skeletally dissimilar shapes: observers could tell shapes apart more accurately when they had different skeletons, compared to when they had objectively larger differences in superficial features but retained the same skeletal structure. Conversely, observers had difficulty appreciating even surprisingly large differences when those differences did not reorganize the underlying skeletons. Additional experiments generalized this pattern to realistic 3D volumes whose skeletons were much less readily inferable from the shape's visible contours: skeletal changes were still easier to detect than all other kinds of changes. These results show how shape skeletons may underlie the perception of similarity — and more generally how they have important consequences for downstream visual processing.

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63.4098 Open vs Closed Shapes: A Dimension of Perceptual Awareness?

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Effective communication using visualization relies in part on the use of viable visual encoding strategies. For example, a viewer's ability to rapidly and accurately discern between two or more categorical variables in a chart or figure is contingent upon the distinctiveness of the encodings applied to each variable. Research in perception suggests that color is a more salient visual feature when compared to shape and, although that finding is confirmed by visualization studies, their data suggest characteristics of shape also yield meaningful differences in distinctiveness. We propose that open or closed shapes (that is, whether it is composed of line segments that are bounded across a region of space or not) represent a salient characteristic that influences perceptual awareness. Two experiments were designed to test the reliability of the open/closed dimension. In the first, a flanker paradigm was used to test whether perceptual load and open/closed feature dimension would modulate the effect of the flanker on target processing. Results showed an influence of both variables. The second experiment used a Same/Different RT task to replicate and extend those findings. Results from both show that responses are faster and more accurate when closed rather than open shapes are processed as targets; and there is more processing interference when two competing shapes come from the same rather than different open/closed feature dimensions. Our results bear implications for the visualization community and can inform recommendations in automated charting software.

63.4099 Evaluating translation invariance in models of shape tuning in area V4

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Computational models of mid-level form processing in the visual cortex have received less attention than those of low-level processing in V1, yet they remain essential for understanding how sophisticated cortical representations arise from simpler ones. To understand how selectivity for contour curvature of simple shapes arises in V4 (Pasupathy and Connor, 2001), we quantitatively compared a variety of relevant models. One of the most promising biologically plausible models is the hierarchical-max (HMAX) model of Cadieu et al. (2007). Any candidate model must explain both the contour selectivity and translation invariance (TI) observed in V4 neurons. We implemented the HMAX model and tested its feature selectivity as a function of receptive field (RF) location using sinewave gratings and closed shapes. We quantified TI as the consistency of selectivity across the RF using Pearson's correlation coefficient. We found that, although it explains shape selectivity at fixed points within the RF, the HMAX model has striking features not reported for V4 neurons: (1) its RF profiles have sharp peaks and valleys and (2) shifting stimuli short distances within the RF may drastically change the shape selectivity function. These undesirable properties arose from the nature of the training and architecture of the model, which we altered in various ways to reveal fundamental limitations of this type of model for achieving V4-like selectivity and invariance. We will discuss these results in the context of our recent work evaluating the performance of deep artificial convolutional neural networks, which are more complex but contain units that are more V4-like. In summary, our quantitative tests and comparisons of models for V4 shape selectivity reveal that even the best biologically motivated models diverge sharply from expected V4 behavior. Our results give insight for developing the next generation of V4 models and implementing experiments needed to further constrain the models.

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63.4100 Behavioral Oscillations in Shape Perception

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Brain activity and function have been shown to oscillate at particular frequencies. These may encode feedback and feedforward processes across different cortical regions and layers. Recently, several studies have found oscillations to also exist in reaction time rates during attentional cuing tasks in the alpha (7-12Hz) and theta (4-8Hz) ranges. Because of convergence with neurophysiological findings and the use of cuing paradigms, these oscillations have been linked to attentional sampling of visual information. We wanted to investigate whether similar patterns in behavior could be observed in perceptual shape processing not explicitly linked to attention. We conducted a series of psychophysical experiments in which subjects saw a fat/thin Kanizsa square stimulus, followed by a local mask, and, after a variable delay (SOA), either a local or a global mask (Ringach & Shapely, 1996). We observed oscillations in performance in a masking paradigm that used no explicit attentional cues. The SOA was titrated in steps of 16.7 ms between 0 and 533 ms. Discrimination accuracy fluctuated by up to ±10% as a function of SOA in the alpha and theta ranges for both local and global mask conditions. Oscillation amplitude was somewhat larger for locally masked stimuli. A control experiment using a 2AFC version of the task showed that these fluctuations were perceptual in nature, and not due to fluctuations in response criterion. We also found that confidence fluctuated with accuracy, indicating that observers were aware when a stimulus was more or less visible. We hypothesize that behavioral oscillations may mirror neural oscillations and may reflect feedback and feedforward signaling in perceptual processes such as contour completion and masking, and are not solely signals of attentional sampling.

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63.4101 **Effects of shape transformations on perceived similarity**
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The visual representation of shape condenses a high-dimensional input image into a smaller set of more informative features. One of the main functions of such representations is to support similarity judgments, so that different shapes can be related to one another and significant features identified. Although distinguishing the causal origin of features is under-constrained, ideally, shapes resulting from similar underlying generative process (e.g. subjected to similar transformations) should be seen as more similar to one another than those created by different processes. To test this, we created sets of novel 2D objects, based on a small number of naturalistic base shapes. Half the shapes in each set were morphs of the base shapes. These non-transformed 'source' shapes were constant across sets. The other half of each set was created by subjecting the source objects to shape-deforming transformations (stretching or bloating to different degrees). Using a multi-arrangements method, observers spatially arranged each set of shapes according to their similarity within a circular arena. The results indicate that transformed shapes were seen as a distinct category from the source objects, but were also arranged in an orderly fashion, closest to their non-transformed counterparts. Thus, participants arranged the sets according to both the source and the transformation, suggesting that they could segment shape features according to their causal origins. Moreover, the larger transformations caused shapes to converge in shape space, suggesting that some generative processes create distinctive signatures in shapes independent of their original form. Representational similarity analysis with mid-level shape features (e.g., contour/skeletal structure) showed that similarities in the transformation and contour of the shapes best account for the participants' arrangements. These results suggest that the visual system represents shapes using context-dependent feature space that takes into account the causal origin of different features.

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63.4102 **Curvature detection shares common mechanisms with vernier task**
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We have been trying to identify the spatial features that determine detection of curvature by using adaptation to three features used by Gheorghiu & Kingdom (2007) to study supra-threshold curvature perception. The features were shape-frequency (cycle number of periodic curvature), shape-amplitude and local curvature. The effect of adaptation was found only after adaptations to shape-amplitude (Morita & Sato, ECVP2016). The threshold found with respect to the shape amplitude was 15'' at 1 deg off from the foveal center, and was comparable to vernier acuity with similar viewing condition. This suggests that curvature detection and vernier acuity tasks were mediated, at least partially by the same mechanism. In this study, we measured and compared detection thresholds for wavy and square-wave line stimuli, both presented at 1 deg away from central fixation point. In the experiments, either wavy- or square-wave vertical line was presented either on the right or left hand side of the fixation, and was paired with straight line presented on the other side. The observer's task was to report which of the paired lines was straight (2AFC). Both types of line stimuli have approximately 1.7 deg of stimulus length, 4 c/deg of shape-frequency and approximately 3 c/m2 of luminance. The threshold measurement was conducted in separate sessions for the two types of line stimuli. If vernier- and curvature-detection tasks were mediated by, at least partially a common mechanism, the two types of stimulus would produce comparable results, and we actually obtained such results. The detection threshold for the two types of stimuli were quite comparable. These results demonstrate that curvature detection and vernier task share common mechanism.

63.4103 **Past Experience Within an Experiment Does Not Influence Figural Assignment**
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Object detection is an important component of scene perception. Figure assignment can assay of object detection. A figural prior is familiar configuration, based on experience outside the laboratory; this experience was probably with the familiar configuration (and therefore its parts) in its typical orientation. We investigated whether exposure to displays sharing familiar parts and/or familiar configuration over an orientation change influences subsequent figure assignment within an experiment. Participants viewed bipartite displays (black/white) that were ambiguous regarding which side (left/right) was the figure except that one side – the critical region – was either a familiar configuration (Fam) or derived from one. The derivations were: Inverted Fam (Inv), Part-Rearranged Configuration (PR), or Inverted Part-Rearranged Configuration (invPR). At the configural level both PR and invPR critical regions were novel. All regions complementary to the critical regions were novel. Critical region contrast (black/white) and location (left/right) were balanced. Stimuli (n = 38) were presented in four blocks. Within blocks all four configurations were presented – but a given stimulus appeared in only one configuration. Across blocks, each stimulus appeared in all four configurations. The order of configurations between blocks was counterbalanced. Hence, we examined whether prior experience with parts and/or configurations influences subsequent figural assignment. Without previous exposure in the experiment (block 1), critical regions were figures more often in Fam (75.6%) than in Inv (68.1%), and in both more often than in PR (56.3%) and invPR (56.0%) (p's < 0.01), replicating previous effects. Reports of critical region as figure increased over block ($p < 0.01$) regardless of configuration. Configuration and block did not interact ($p > 0.1$), suggesting no effect of experience within the experiment. At least with controlled display presentation conditions (> 18 exposures between appearances of a given stimulus in different configurations), effects of past experience with an experiment do not emerge.

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63.4104 **Further evidence for the global processing of random phase radial frequency patterns.**
Robert Green[1](robert.green@research.uwa.edu.au), James Dickinson[1], David Badcock[1]; [1]School of Psychology, The University of Western Australia, [2] , [3]

The detection and recognition of combinations of lines and curves composing simple shapes is a primary function of the human visual system. Previously, researchers have used circular contours with sinusoidal deformation of the radius (radial frequency (RF) patterns) to investigate the underlying processing involved in simple shape perception. It was suggested that these patterns exhibited global processing, improvement in detection of modulation for larger extents of modulated contour which could not be accounted for probabilistically. However, recent research has questioned the global processing of RF patterns (Baldwin, Schmidtmann, Kingdom, & Hess, 2016) and suggested that processing of these patterns is similar to that of modulated lines (Mullen, Beaudot, & Ivanov, 2011). The current study investigates these claims using fixed phase (where the local elements have spatial certainty), and random phase (where the local elements have spatial uncertainty) for both RF patterns, and modulated lines. Thresholds were collected for eight naïve observers and compared to probability summation estimates calculated using both high threshold theory and signal detection theory. Results demonstrated strong evidence for the global processing of random phase RF patterns and evidence for an interaction between local and global cues for fixed phase RF patterns. We also found an increase in sensitivity between 1, and 2 cycles of modulation, but not between 2, and 3 cycles of modulation for the modulated line stimuli. The results provide further evidence for the global processing of random phase RF patterns and indicate that RF patterns and modulated lines are processed differently.

63.4105 **The one-is-more illusion: Sets of discrete objects appear less extended than equivalent continuous entities in both space and time**
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Our visual experience is populated by both discrete objects (e.g. people and posters) and continuous entities (e.g. long walls on which posters may be affixed). We tend to distinguish such stimuli in categorization and language, but might we actually see such stimuli differently? Here we report a vivid illusion wherein discrete 'objecthood' changes what we see in an unexpected way — the one-is-more illusion. Observers viewed pairs of images presented simultaneously, and simply made a forced-choice judgment about which image looked longer (i.e. more spatially extended). One image was always a single continuous object (e.g. a long rectangle), and the other was a collection of discrete objects (e.g. two shorter rectangles separated by a gap). Across several types of images, observers perceived the continuous objects as longer than equated discrete objects, and this illusion was both large and exceptionally reliable (binomial test, $p < .000001$). In fact, observers often perceived the continuous objects as longer even when the discrete objects were in fact longer. Critically, the illusion persisted even when the images were equated for properties such as the number of intervening contours (e.g. when contrasting two rectangles vs. a single rectangle interrupted by a visible occluder). Moreover, this illusion extends beyond space, and also operates in time: when comparing two sequentially presented auditory stimuli, continuous tones were perceived as lasting longer than equated sets of discrete tones. Whereas previous work has emphasized the importance of objecthood for processes such as attention and visual working memory, these results often come out only in the statistical wash. In contrast, the one-is-more illusion provides a striking demonstration of how the segmentation of a display into discrete objects can change the perception of other visual properties in a way that you readily see (and hear!) with your own eyes (and ears!).

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63.4106 **Amodal completion requires more time in older adults** Jessica Cali[1](calij@mcmaster.ca), Patrick Bennett[1], Allison Sekuler[1]; [1]Psychology Neuroscience & Behaviour, McMaster University

In everyday settings, objects frequently partially occlude each other. Thus, amodal completion is critical for object recognition in naturalistic contexts. However, the effects of aging on amodal completion remain unexplored. Therefore, we measured the extent and time course of amodal completion for younger and older adults using a shape discrimination task in which subjects judged the orientation of a moving rectangle as horizontal or vertical (Murray, Sekuler & Bennett, 2001). Observers completed three conditions: 1) complete, with the entire outline of the rectangle visible; 2) fragmented, with corners of the rectangle deleted; and 3) occluded, resembling the fragmented condition, except with corners occluded by opaque squares. In younger observers, this task is easiest with complete stimuli and most difficult with fragmented. Performance with occluded stimuli resembles that of complete or fragmented, depending on the extent to which the observer amodally completes the rectangle behind the occluders. Specifically, Murray et al. found that the younger adults performed the complete and occluded tasks similarly at stimulus durations longer than ~60 ms. We measured thresholds for each condition at stimulus durations ranging from 15-210 ms, determining the aspect ratio that led to 70% correct. Based on initial results from 10 participants, shape discrimination is impaired for older (M=69 years) vs younger (M=23 years) adults. At the shortest durations, older observers require larger aspect ratios than younger subjects to discriminate even complete shapes accurately, and fail to reach 100% accuracy even with large aspect ratios. Performance is similar across age groups for complete shapes at longer durations. Critically, our data suggest that older adults require more time than younger adults to amodally complete occluded objects (>100 ms vs ~60 ms). We currently are investigating the result further with a larger group of subjects, to determine the time for completion in older observers more precisely.

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